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SEVENTY FIVE YEARS OF THE FACULTY OF EXERCISE AND SPORT SCIENCES OF THE UNIVERSITY OF TARTU

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The predecessor of the Faculty of Exercise and Sport Sciences of the University of Tartu was the Institute of Physical Education that was founded in the Faculty of Medicine in 1928 [10]. Following World War II, in 1945 the institute was raised to the status of a faculty. The Faculty of Exercise and Sport Sciences at the University of Tartu was unique in the whole of the former Soviet Union — everywhere else higher education in the field of physical education and sport was provided either in independent physical education institutes or in the corresponding departments of teacher training colleges.

The main task of the Institute of Physical Education was training physical education teachers and sport instructors for armed forces. In the post-war period the focus was on physical education, since 1954 students were admitted separately for the qualification of either physical education teacher or coach. In 1973 the faculty specialized on preparing coaches, although the curriculum retained subjects that provided students with certain knowledge and skills in the field of physical education at school.

The major social changes in the beginning of the 1990s and the regaining of independence in Estonia brought along considerable shifts in the organization of university studies. The education began to be based on degrees, the corresponding levels being Bachelor's, Master's and Doctoral degree. In the Faculty of Exercise and Sport Sciences was launched the curriculum of Exercise and Sport Sciences, in the framework of which students could specialize either on coaching (there were 17 options for different sport events), physical education or physiotherapy. Since the 1995/96 academic year the new teacher training system was introduced at the university, according to which teacher's certificate was acquired following the one-year post-baccalaureate teacher training course. From that time on the faculty conducts teacher training programs for physical education and health education teachers. Unfortunately, neither at the university nor in Estonia as a whole the faculty found interested partners who would have supported the developing of the education of coaches according to the same pattern. Consequently, coaches were trained within the 4-year Bachelor program.

The next substantial changes in the organization of studies in the faculty occurred in 1997: Physiotherapy evolved into an independent Bachelor-level curriculum besides Exercise and Sport Sciences, the diploma program of Coaching and Sport Administration was launched and the first 5 students were admitted into Open University. In 1999 the faculty was awarded the International Olympic Committee prize for long-term successful promotion of education and sport.

Following the university education reform of 2002, the faculty conducts studies according to the curricula of Physical Education and Sport, and Physiotherapy on both Bachelor and Master level. The Master curriculum of Physical Education and Sport offers students three options for specialization: physical education teacher — coach, physical education and health education teacher, and coach — sport manager. The first and the third option encompass coaching education on a concrete sport event out of the total of twenty. The Master-level curriculum in Physiotherapy offers four branches of specialization: children's, adults', geriatric or sport physiotherapy. The Doctoral-level education is conducted according to the program of Exercise and Sport Sciences.

The beginning of research in the field of physical education and sport at the University of Tartu dates back to the time prior to the founding of the Institute of Physical Education. In the first years of the last century K. Dehio and E. Masing did research in the area that can today be regarded as exercise physiology [27]. In the Institute of Physical Education research was not a priority [27], however, lecturers published valuable books on the methods of physical education [5], sport training [14] and issues of sports medicine [6]. Research in exercise physiology at the University of Tartu was conducted in the Faculty of Medicine, the more distinguished representatives in the 1930s being professors A. Fleisch, who also taught in the Institute of Physical Education, and M. Tiitso, who in his experiments extensively used the original equipment elaborated by A. Fleisch. Prof M. Tiitso was for a short period of time the head of the Institute of Physical Education [10].

In the post-war Faculty of Exercise and Sport Sciences the scope of research on physical education and sport expanded, being supported at first by experienced supervisors from other university faculties. In addition to exercise physiology issues, the problems of training methods [12], history of sport [20] and sport psychology [16] began to be researched. In the 1960s and 1970s the studies on training methodology were carried further [3, 9, 15, 17], other issues researched included the selection of junior athletes [11], physical education [13] and sport sociology [1, 21]. The studies on biomechanics were focused on the analysis of the technique of different sports events and the condition of athletes' muscles by applying biomechanical methods. The original methods and equipment were elaborated for assessing the condition of muscles [22] that is being used in several countries in clinical and sport science-related research and practice. Without underestimating the results achieved in other areas, it still remains an undisputed fact that during the Soviet period, the research in the areas of exercise physiology and biochemistry developed to the more significant level qualitatively in the faculty. The respective results have been summarized in several monographs [23, 24, 25, 26, 28].

At present the faculty includes the Institute of Exercise Biology and Physiotherapy and the Institute of Sport Pedagogy and Coaching. Studies and research are organized according to the profile of chairs. There are three chairs in each institute and the majority of them possess the necessary laboratories and equipment for conducting research. The Institute of Exercise Biology and Physiotherapy includes the following chairs: Functional Morphology (head prof T. Seene), Kinesiology and Biomechanics (prof M. Pääsuke) and Exercise Physiology (prof V. Ööpik). In the Institute of Sport Pedagogy and Coaching the structure units are the chairs of Sport Pedagogy (prof T. Jürimäe), Coaching (prof A. Nurmekivi) and Social Sciences in Sports (assoc prof L. Raudsepp).

Two research groups of kinanthropometry (head prof T. Jürimäe) and nutrition and exercise physiology (prof V. Ööpik) belong to the interdisciplinary Estonian Centre of Excellence in Behavioural and Health Sciences. The centre is one of the total of six that successfully participated among 30 applicants in the relevant competition arranged by the Ministry of Education in 2001 [2].

In recent five years there has been constant rise in the number of research articles published by lecturers and researchers of the faculty, as well as the number of articles published in international journals. In the peer-reviewed journals referred by ISI, Medline and SCI have in recent years annually appeared 20–29 research publications by faculty employees. Two monographs have been published by faculty members in internationally recognized publishing houses [4, 29]. The faculty has organized all-Estonian conferences “Science, Sport and Medicine” on a regular basis [7, 8]. The organization of two international scientific conferences with a great number of participants in Tartu in 2001 and 2002 on the initiative of prof T. Jürimäe was a major task, accomplished successfully [18, 19].

Due to its specific features, the faculty has throughout years integrated studies with research and sport. Several lecturers are also outstanding coaches, beginning with the first dean F. Kudu, of whose pupils several decathlonists attained top level in the world. Distinguished coaches were also E. Abel and H. Abel (skiing), I. Kullam and E. Naarits (basketball), A. Tähnas (wrestling), V. Truumaa (volleyball), E. Kübarsepp and R. Roos (handball), A. Pisuke and M. Kutman (track and field), L. Uustal, E. Kudu, H. Tidriksaar and L. Martis (gymnastics), and many others. At present the faculty staff includes several lecturers who have achieved significant results in coaching. M. Kutman, A. Laos and V. Kade participate in teaching the respective sports of track and field, basketball and boxing. M. Visnapuu is the most successful women’s handball coach in Estonia of recent years, H. Lemberg supervises several top runners, M. Viru and T. Torop work with sprinters and P. Päll with power lifters, E. Tõnisson is a recognized wrestling coach. K. Kaarna who was recently elected teacher of sports games is the second coach of Estonian women's and girls' football team. Several faculty members are directly and actively engaged in promoting Estonian sport: H. Lemberg, T. Matsin and T. Torop belong to the board of the Estonian Athletic Association, I. Neissaar is member of the board of the Estonian Gymnastics Federation, A. Pehme belonged for years to the board of the Estonian Judo Association, M. Visnapuu heads the educational program of the Estonian Handball Federation, E. Tõnisson is chairman of the board of coaches of the Estonian Wrestling Federation. T. Jürimäe is vice-chairman of the board of the Estonian Physical Education Association, a very important post in regard of the faculty. V. Ööpik belongs to the board of the Estonian Wrestling Federation, is vice-chairman of the Estonian Coaches' Association and president of the Estonian Olympic Academy.

At present, as of 1 October 2003, there are 611 students in the Faculty of Exercise and Sport Sciences of the University of Tartu on all study levels, including 185 in the Open University (distance education). There are 55 faculty staff members employed full- or part-time, including 33 lecturers, 10 researchers, and 12 assisting personnel members.

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BIOMECHANICAL ANALYSIS OF THE POLE VAULT IN NATIONAL COLLEGIATE COMPETITION

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ABSTRACT

The following is a study of the NCAA pole vault competition that took place in 2000 at Duke University in Durham, NC. There were 9 vaulters and 19 successful vaults analyzed ranging from 5.15 to 5.6 m. A two-dimensional videoanalysis at 60 Hz was performed and many linear and angular kinematic parameters were measured. The Ariel Performance Analysis System was used to process the video data. The pole vaulters were consistently "under" at the pole plant by 0.45 m and still "under" at the take-off by 0.16 m. The horizontal velocity showed a decrease from 9.8 m/s between the 3rd and 2nd last steps, to 9.44 m/s between the 2nd and last steps, to 8.6 m/s at pole plant, and to 7.6 m/s at take-off. Some energy transformations from horizontal kinetic energy to strain energy in the pole were already occurring prior to the time of take-off. The maximum pole bend was measured as the minimum distance from the top hand to the bottom of the box and was 3.32 m. The extension of the body followed by the turn and push were less than optimal due to the straightening effect of the pole and the shallow angle of the projection of the CG from the pole at pole release. This study provides current data on collegiate class vaulters that coaches and researchers can use for comparative and new research purposes.

Key Words: kinematics, videoanalysis, energy transformation

INTRODUCTION

Twenty-two years before the 2000 NCAA pole vault competition at Durham, NC, this author filmed the 1978 NCAA pole vault in Eugene, OR with 16 mm cinematography, and presented an analysis of the winning vault at the 1978 International Congress of Sports Sciences, in Edmonton, Alberta [2]. The winning height in 1978 was 5.54 m (18'2") and the winning height in 2000 was 5.6 m (18'4 ½"). Although the winning heights were similar, the world record and number of vaulters over 5.5 m (18') and 5.8 m (19') has increased greatly.

The pole vault event is very complex and the past research has focused on many different parameters to try to explain the important aspects of the vault. Computer simulations have been done in order to model the parameters and predict what would occur with manipulation of the parameters [6, 10, 12, 13]. Other studies have focused on energy transformations that occur when the athlete attempts to transform the linear kinetic energy of the run into strain energy of the pole and finally into potential energy of the height of the center of gravity [5, 8]. Other studies have just measured some of the kinematic parameters and reported the findings [1, 4, 9, 11]. It is the purpose of this study to measure the parameters of the vault that have been commonly measured before, and also to determine other parameters, that increase the understanding of the mechanical characteristics that lead to successful pole vaulting and contribute to the database.

MATERIALS AND METHODS

The pole vault event of the 2000 NCAA outdoor track and field competition at Duke University was videotaped in its entirety. There were 9 vaulters who had a total of 19 successful attempts. The Panasonic SVHS camcorder was set up in the stadium stands with the optical axis of the camcorder perpendicular to the pole vault runway and level. The field of view included the 7.62 m of runway before the top of the box and about 3 m behind the box (into the pit area). Markers were set at 4.57 m and 6.1 m on the runway, as well as a vertical 1.524 m cube with one side in the plane of the motion and positioned with one corner at the 4.57 m mark. Top of box and bottom of box were not visible to the camera, but were calculated in pixels from measurements on the runway and with a pole placed vertically in the box. The pixel numbers were used to register the frames of each vault. Only successful vaults were analyzed. The camcorder speed was 60 frames per second. There were 19 points digitized of which 14 were body landmarks. Three points represented the pole, with a middle point placed on a visible mark. A point was placed at each end of the cross-bar. The Ariel Performance Analysis System was used to digitize the sequences, and to calculate the body center of gravity, and the linear and angular kinematics. The data was smoothed using a cubic spline function. Certain parameters were exported to an Excel spreadsheet where other calculations were made, such as: distance of top hand to butt end of pole, angle of plant from top hand to bottom of box with the horizontal, etc.

The vaulters had an average height of 181.7±6.55 cm, an average body weight of 772±63.8 N, and an average body mass of 78.7± 6.42 kg. See Table 1 for the individual measurements.

Time was oriented from the moment the center of gravity (CG) reached the peak height during the vault. That was designated 0.0 seconds and all events before that moment were positive, but decreasing from the time the first frame was digitized until the peak height of the CG was reached. Any events occurring after that moment were negative. By using the peak height of the CG as a synchronizing event, comparisons of events could be made between vaulters and between vaults of the same athlete. The take-off of each foot during

TO3, TO2, and TO1 (take-off) was defined as the first frame after the foot broke contact with the runway, and pole-release was defined as the first frame after the TH left the pole.

Table 1. Pole vaulter's body dimensions and successful vaults

Vaulter		Height (cm)	Weight (N)	Mass (kg)	Successful Vaults Analyzed (m)
A		183	735	75	5.4, 5.5
B		190.5	868	88.6	5.4
C		178	784	80	5.5, 5.6
D		185.4	691	70.5	5.3
E		180.3	779	79.5	5.3, 5.4, 5.5, 5.6
F		185.4	832	84	5.15, 5.4
G		170	735	75	5.3
H		175	691	70.5	5.3, 5.4, 5.5
I		188	833	85	5.3, 5.4, 5.5
	Mean	181.7	772	78.7	
	S.D.	6.55	63.85	6.42	

The following analysis began with the third last foot placement before the take-off and continued until the body cleared the crossbar. See Figures 1, 2, and 3, which are sequence diagrams of vaulter "C" clearing 5.6 m. The Approach/Pole Plant (PP), Take-Off (TO) (Figure 1), Hang-Swing , Swing-Tuck (Figure 2), Extension, Pull/Turn, Push-Off (Figure 3) are the phases that were analyzed.

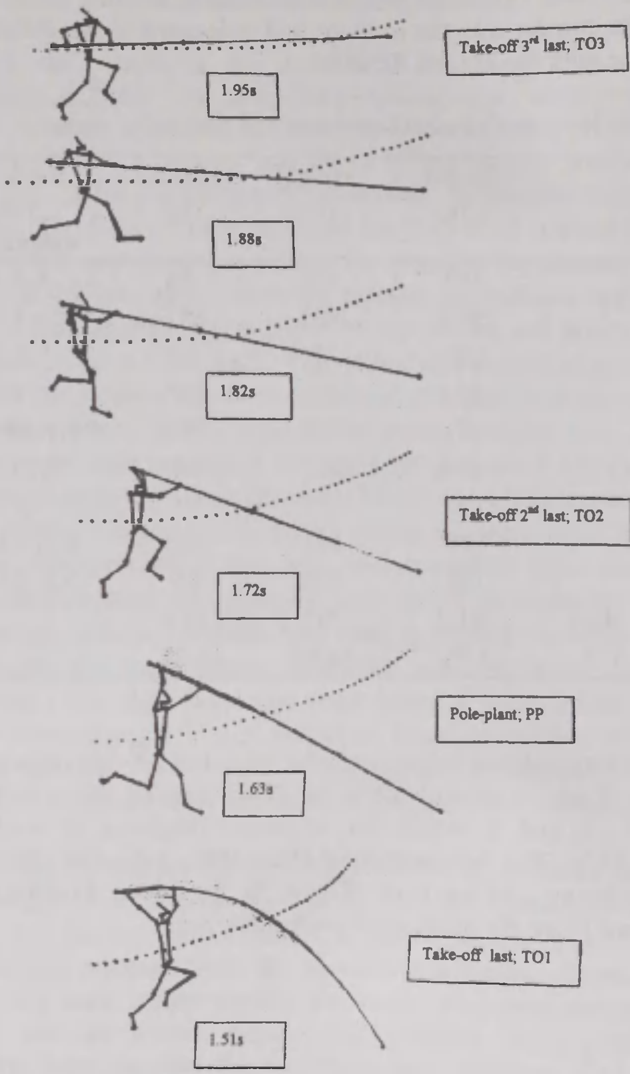

Figure 1. The Approach and Pole Plant Phases

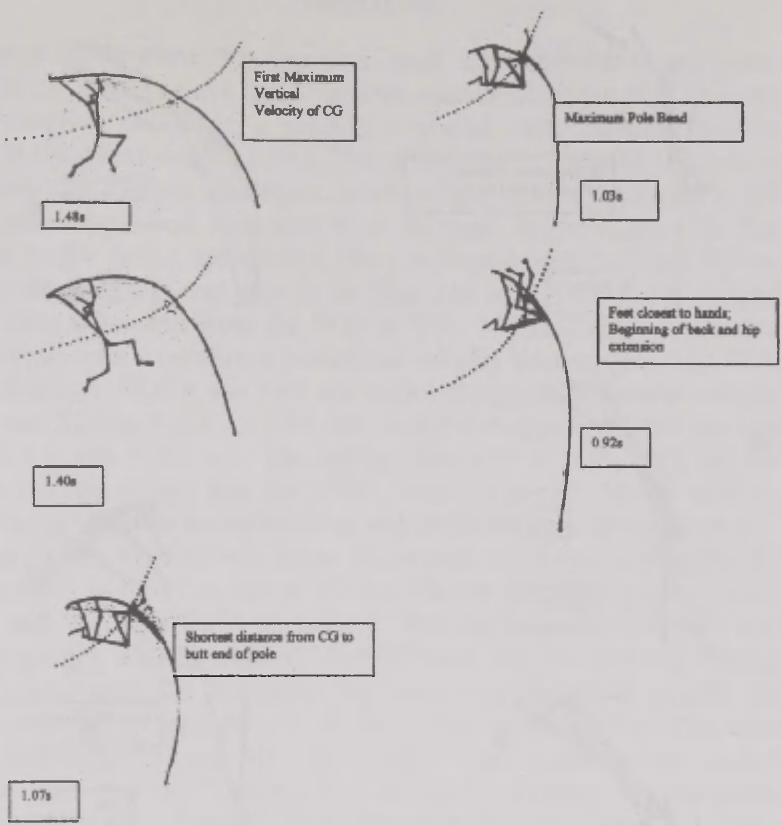

Figure 2. Hang-Swing and Swing-Tuck Phases

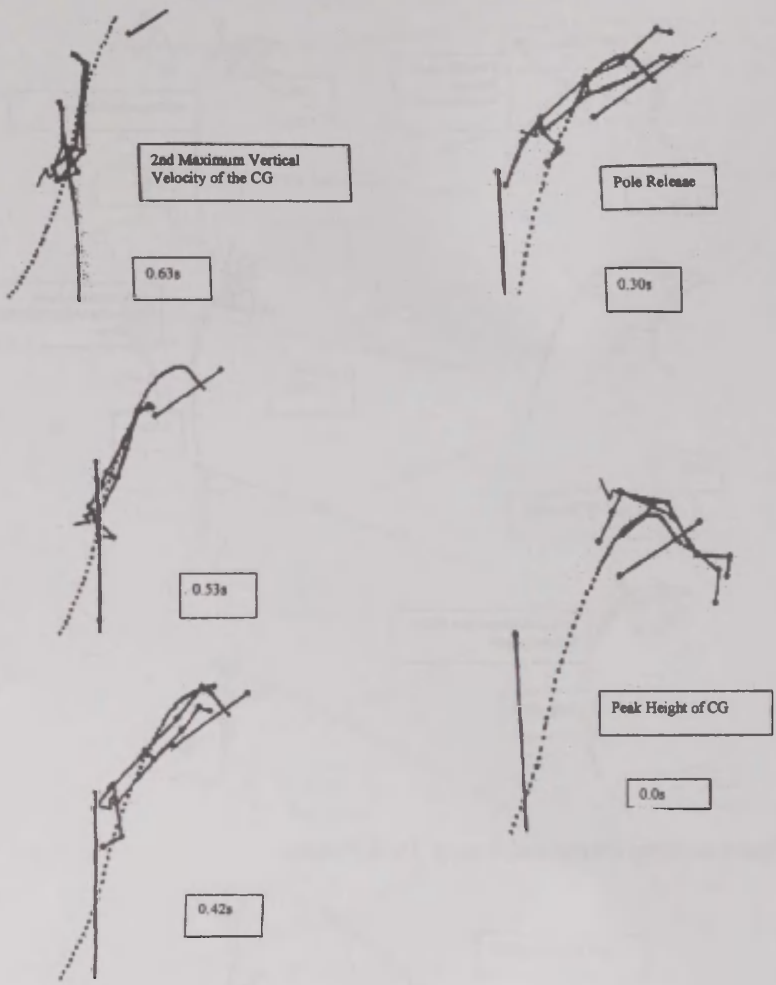

Figure 3. Extension, Pull/turn Phases, and Push Off Phases

RESULTS

Approach/Pole Plant: The last three steps were included in this phase (Figure 1). During these three steps the vaulter raised the pole from the side carrying position to a position overhead while directing the butt end of the pole toward the box. This phase ended when the butt end of the pole met the box. The times listed in Table 2 for the take-off of the last three steps were measured from the peak height of the CG. The stride length during the last two steps decreased from 2.15 to 1.915 m. The pole plant occurred prior to the final take-off (TO1). The horizontal velocities decreased from the TO3 to TO1. At TO3 the velocity was 9.666 m/s with a maximum horizontal velocity between TO3 and TO2 of 9.8 m/s. At TO2 it was 9.41 m/s with a maximum horizontal velocity between TO2 and TO1 of 9.44 m/s. At PP it dropped to 8.645 m/s and at TO1 it was 7.582 m/s. The vertical velocities at TO3, TO2, and PP were less than 1 m/s, however at TO1 it increased to 2.156 m/s showing a jumping effect by the take-off leg and/or the lifting effect of the pole.

At PP the TO foot was closer to the box, horizontally, than the top hand (TH) by 0.457 m, but at TO the TH had moved closer to the TO foot but was still 0.157 m behind. This showed that the pole was undergoing a bending moment after PP while the TO foot was striking the ground until TO. Normally, the coach tells the athlete to plant the pole with the top hand directly above the toes of the TO foot. This does not seem to be the case. All of the vaulters were at least 34 cm "under" at the plant, with the TO foot closer to the box than the TH. The height of the TH at the PP was 2.07 m, but increased to 2.17 m at TO. Since the vertical velocity increased to 2.156 m/s and the height of the TH increased from 2.07 to 2.17 a jumping motion is also supported.

The kinetic energy at the moment the maximum X-velocity is reached between TO2 and TO1 was 3506 Nm, however at PP it had dropped to 2953 Nm due to the retarding force of the pole in the box. At TO it had dropped to 2448 Nm.

Take-Off Phase: The Take-Off phase began at the instant of the Pole Plant and ended when the TO foot left the runway at TO1. The horizontal distance from the top hand to the top of the box was 4.14 m

Table 2. Approach and Pole Plant parameters

	Mean	S.D.
Time of take-off of 3rd last foot (s) (TO3)	1.944	0.053
Time of take-off of 2nd last foot (TO2)	1.715	0.046
Time of pole plant (TPP)	1.618	0.048
Time of take-off of last foot (TO1)	1.523	0.043
Distance from 3rd last foot to box (m) (DTO3)	8.004	0.191
Distance from 2nd last foot to box (DTO2)	5.844	0.161
Distance from last foot to box (DTO1)	3.930	0.076
Stride length from DTO3 to DTO2 (SL32) (m)	2.150	0.145
Stride length from DTO2 to DTO1 (SL21)	1.915	0.160
X-velocity of CG at TO1 (VXTO1) (m/s)	7.582	0.273
Y-velocity of CG at TO1 (VYTO1)	2.156	0.348
X-velocity of CG at PP (VXPP) (m/s)	8.645	0.369
Y-velocity of CG at PP (VYPP)	0.934	0.374
X-velocity of CG at TO2 (VXTO2) (m/s)	9.410	0.304
Y-velocity of CG at TO2 (VYTO2)	0.252	0.219
X-velocity of CG at TO3 (VXTO3) (m/s)	9.666	0.394
Y-velocity of CG at TO3 (VYTO3)	0.340	0.144
X-distance from TO foot to TH at PP (m) (+ foot closer to box)	0.457	0.226
X-distance from TO foot to TH at TO1	0.157	0.078
Y-distance of TH at PP (m)	2.070	0.059
Y-distance of TH at TO (m)	2.174	0.082
Maximum X-Velocity of CG between TO2 and TO1 (VXMAX1) (m/s)	9.439	0.321
Maximum X-Velocity of CG between TO3 and TO2 (VXMAX2) (m/s)	9.789	0.308
Kinetic energy at maximum X-velocity of CG between TO2 and TO1(Nm)	3506	265
Kinetic energy at PP (Nm)	2953	371
Kinetic energy at TO1 (Nm)	2448	163
Potential energy above H1 at HP	3382.2	260.3

and the vertical distance from the TH to the runway was 2.14 m, yielding an angle of the pole cord from the TH to the top of the box of 27.3 degrees (Table 3). The horizontal velocity decreased from a high of 9.789 m/s to 7.582 m/s at TO (Table 2). This reduction occurred due to a jumping action of the vaulter and the bending of the pole prior to TO. The TO foot was placed 0.455 m under the TH at the pole plant and at TO it was still 0.157 m under. As a result of the decrease of horizontal velocity (kinetic energy), some energy was stored in the pole as strain energy prior to TO. This process continued until maximum pole bend. The height of the CG at TO was 1.27 m and is designated H1 [7]. The acceleration of the CG both horizontally and vertically at the PP and TO are shown in Table 3. Although the standard deviations are considerable one can see that there was a significant force decelerating the body from the PP through the TO. It was about 1.0 to 1.5 times body weight (BW). Vertically there was also a significant force greater than 1.5 times BW raising the body at the pole plant, which reduced to about 58% of BW at TO. The angle of the velocity vector at TO was 15.9°.

Table 3. Take-off Phase parameters

	Mean	S.D.
X-distance TH from top of box at TO (m)	4.136	0.129
Y-distance TH at TO	2.135	0.068
Angle of cord from TH to top of box at TO (deg)	27.31	1.081
X-acceleration of CG at PP (m/s/s)	15.720	6.443
X-acceleration of CG at TO1	–9.825	5.436
Y-acceleration of CG at TO1	5.722	4.359
H1: Height of CG at TO (m)	1.266	0.059
Angle of velocity of CG at TO (deg)	15.87	2.550
Angle of TH to top of box at TO	27.31	1.081

Hang Swing and Swing Tuck Phases: The Hang-Swing phase begins when the vaulter leaves the runway at TO, and ends when the hip angle reaches maximum. The vaulters averaged a maximum hip angle of 219.1° at a time of 1.407 s. The swing-tuck phase began when the hip angle reached its maximum, after which the hips began to flex to a maximum angular velocity of –1053.4 deg/s, at a time of 1.217 s and at a hip angle of 128.5°. The maximum hip flexion angular velocity occurred 0.184 s prior to maximum pole bend, and 0.093 s before the CG was closest to the box. The swing-tuck ended when either foot got closest to the top hand.

In Figure 1, the TO of vaulter "C" occurs at 1.51 s prior to the HP, the peak height of the CG. At TO, there is an immediate lifting of the body by the pole during the bending of the pole. At 1.46 s for the average vaulter, the vertical velocity of the CG was 2.36 m/s, a first maximum vertical velocity, and the horizontal velocity at that moment decreased to 7.02 m/s. In most of the vaulters, there was a drop in the vertical velocity to 1.741 m/s immediately after this first maximum vertical velocity at 1.253 s, and the horizontal velocity decreased to 4.88 m/s at that time. In Figure 4, the horizontal and vertical velocity of the CG of vaulter "C" clearing 5.6 m shows that the first peak in vertical velocity was 2.13 m/s, then dropped to 1.96 m/s, and finally rose to a peak vertical velocity of 5.37 m/s. Notice that the feet got closest to the hands at 0.93 s. In the average vaulter (Table 4) the feet got to 0.197 m of the TH at a time of 0.847 s before HP.

Maximum Pole Bend was achieved at 1.033 s and was 3.32 m, but the shortest distance from the CG to the bottom of the box (bbox) occurred just before MPB at 1.124 s at a distance of 2.628 m. This is important because of the compound pendulum mechanics.

Table 4. Hang-Swing and Swing-Tuck Parameters

	Mean	S.D.
VYCGMX1: First Peak Y-velocity of CG after TO (m/s)	2.356	0.255
VXCGMX1: X-velocity of CG at first peak Y-velocity of CG (m/s)	7.016	0.521
Time of first peak Y-velocity of CG (s)	1.462	0.085
VYCGMin: Drop in vertical velocity of CG after first peak (m/s)	1.741	0.319
VXCGMin: X-velocity of CG at the drop in Y-velocity of CG (m/s)	4.884	0.850
Time of drop in Y-velocity of CG (s)	1.253	0.103
VYCGMX2: Second Peak vertical velocity of CG after TO (m/s)	5.283	0.487
VXCGMX2: X-velocity of CG at 2nd peak Y-velocity of CG (m/s)	1.589	0.321
Time of 2nd peak Y-velocity of CG (s)	0.578	0.046
Maximum Hip angle (deg)	219.1	9.28
Time at maximum hip angle (s)	1.407	0.062
Maximum Hip flexion angular velocity (deg/s)	–1053.4	211.1
Time of maximum Hip angular velocity (s)	1.217	0.056
Hip angle at maximum hip angular velocity (deg)	128.5	33.23
MPB: Maximum Pole Bend (m)	3.320	0.121
Time of MPB (s)	1.033	0.044
Distance from CG to bottom of box (bbox) at MPB (m)	2.693	0.089
Distance from TH to CG at MPB (m)	0.705	0.074
Shortest Distance from CG to bbox (m)	2.628	0.089
Time at shortest distance from CG to bbox (s)	1.124	0.049
Distance from TH to CG at shortest distance from CG to bbox (m)	0.863	0.061
Minimum Distance between TH and either foot DTHFMIN (m)	0.197	0.106
Time of DTHFMIN (s)	0.847	0.085

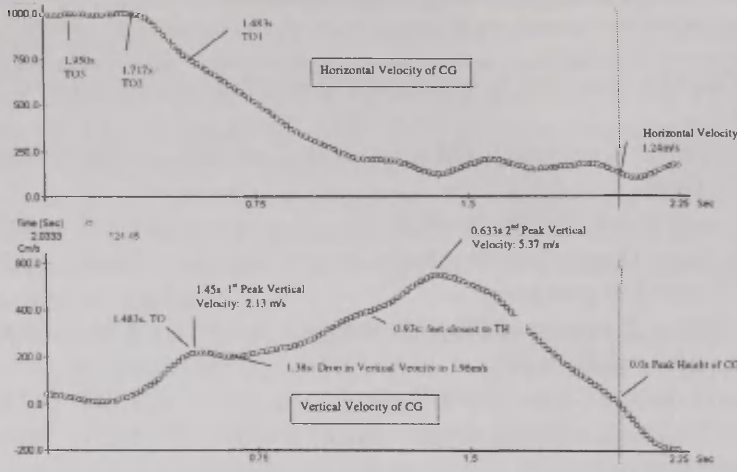

Figure 4. Horizontal and Vertical Velocity of the CG; Vaulter "C" at 5.6m (Note: time on the abscissa oriented from first frame at 0.0s. Time relative to Peak Height of CG marked on the curves, the ordinate is in cm/s)

Extension, Pull/turn, and Push-Off Phases: The Extension phase begins at the moment the feet are closest to the TH (Figure 2), and the hips begin to extend. This occurred at 0.847 s and the distance was 0.197 m (Table 4). The feet are directed upward as the hips and trunk extend. At the same time the pole is straightening. At 0.578 s the vertical velocity of the CG increased to a maximum 5.28 m/s, and the horizontal velocity decreased to 1.589 m/s. Notice that the angle of the path of the CG the second maximum vertical velocity of the CG in Table 5, was 73.35°, while at PR it dropped to 51.14°. This shows that as the pole straightened the angle of projection dropped. Another way of expressing this problem is to look at the depth of the CG at HP from the position of the TH at PR. The TH is at X: –0.163 m and Y: 4.59 m and the position of the CG at HP is at X: 0.755 m and Y: 5.643 m. This is an angle of 48.3°. The push off distance above the TH was 1.053 m (Figure 5). The distance from the PR position of the top hand (–0.163, 4.590) to the position of the CG at HP, the highest point achieved by the CG (0.755, 5.643), was 1.41 m.

Table 5. Extension, Pull/turn, and Push-Off Parameters

	Mean	S.D.
HPR: Height of TH at Pole release (m)	4.590	0.149
X-distance of TH at Pole release (+ behind box)	–0.195	0.172
Time at PR (s)	0.233	0.071
HCGPR: Height of CG at PR	5.353	0.200
HP: Peak Height of CG (m)	5.643	0.135
X-distance of CG at peak (+ behind box)	0.755	0.167
H1: Height of CG at TO (m)	1.266	0.059
H2: Difference between HCGPR and H1	4.087	0.196
H3: Difference between HCGPR and HP	0.291	0.165
H4: Difference between HP and Bar Height	0.235	0.076
H: Difference between HP and H1	4.377	0.147
Hpush: Difference between HPR and HP	1.054	0.155
Angle of Projection of CG at PR (deg)	51.14	11.4
Greatest angle of Trunk with horizontal (deg)	63.62	7.18
Angle of the path of CG at VYCGMX2 (deg)	73.35	3.39
Depth of TH at PR (+ behind box) (m)	–0.163	0.195
Depth of CG at HP (m)	0.755	0.167
HTHPR: Height of TH at PR (m)	4.590	0.149
Angle with Horizontal between position of TH at PR and CG at HP (deg)	48.3*	

* calculated from the mean X–Y coordinates of the TH and height of CG at Peak

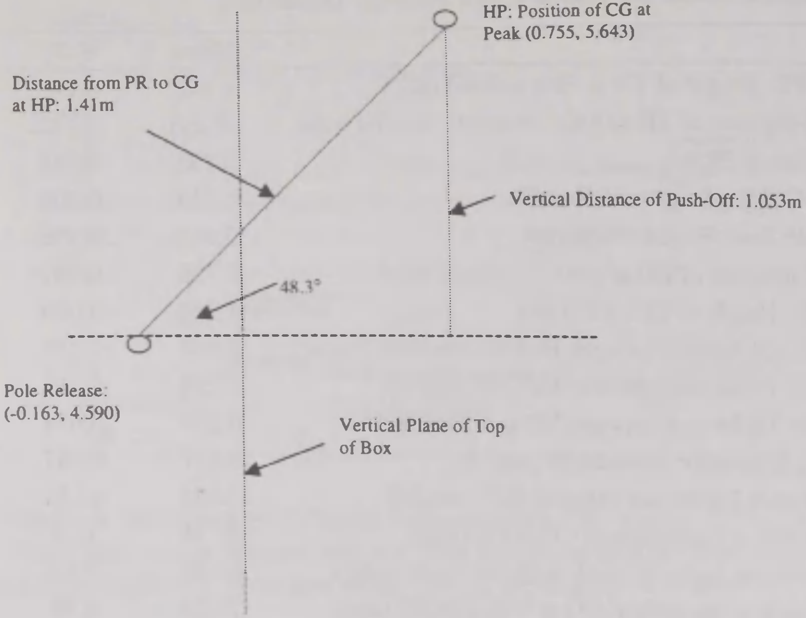

Figure 5. Angle with Horizontal between the position of Pole Release and position of CG at HP

DISCUSSION

The approach run must attain the highest possible horizontal velocity, however there must be a transition between this high velocity and the placement of the pole in the box in order to take-off. The horizontal kinetic energy built up during the run is partially transferred to the pole before the body actually leaves the runway, and the vaulter must reach as high as possible with the top hand in order to apply much of that energy to the bending of the pole while keeping enough horizontal energy to penetrate through the plane of the crossbar. The results showed that the vaulters reached a higher velocity from the third last step to the second last step of 9.78 m/s, which dropped to a maximum of 9.44 m/s between the second last step and the last step (take-off). Before the TO1, the actual take-off, the pole was planted and the velocity slowed down to 8.64 m/s. The actual velocity of TO was 7.58 m/s horizontally and 2.16 m/s vertically (resultant = 7.88 m/s). The resultant was less than the 8.17 m/s reported by Angulo-Kinzler [1]. The last two strides from TO3 to TO2, and from TO2 to TO1 shortened from 2.15 to 1.915 m. Since the pole was planted and forced to bend before the TO of the last foot, the distance from the TH to the bottom of the box shortened. At the moment of the pole plant the TO foot was 0.46 m “under”, or closer to the box than the TH horizontally. At TO, however that distance was reduced to 0.16 m, but still “under”. It seems that the vaulters anticipated that the bending of the pole prior to take-off would require them to be under so that at TO the foot would be closer to the TH horizontally.

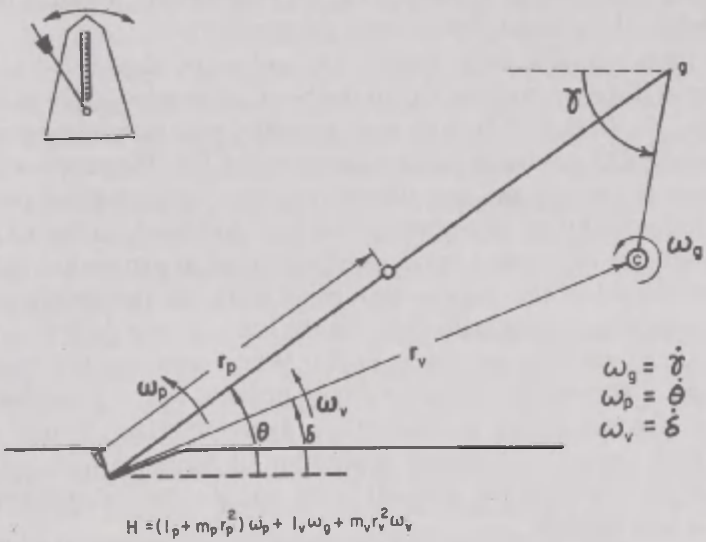

Figure 6. Angular momentum of the vaulter-pole system

Once the vaulter left the runway, they made an effort to keep their body elongated, while pushing with their bottom hand to keep their body away from the pole and retard the forward swinging motion of the body. This kept their body from prematurely rocking back, and also provided a force-couple (bending moment) to bend the pole. The pole is an inverted pendulum rotating around the bbox and the body is a pendulum rotating around the TH or both hands. If one considers a metronome (see Figure 6), the lower the weight is on the inverted pendulum the faster the pendulum oscillates, or the pole reaches vertical quicker. Conversely, as the weight is raised (increased distance of the CG of the weight from the axis of rotation of the inverted pendulum) the slower the rate of oscillation, or the harder it is to get the pole to vertical. This is similar in the vault during the Hang-Swing phase. If the vaulter keeps the body elongated it retains a long distance from the TH to the CG in an attempt to keep the CG closer to the bbox. The shorter the distance of the CG to the bbox the faster the movement of the pole-body system to vertical (called penetration). Vaulters need to emphasize this elongated position to get penetration.

The maximum pole bend was 3.32 m and occurred at 1.033 s, but the shortest distance from the CG to the bbox occurred at 1.124 s. This meant that the flexion of the hips was occurring prior to maximum pole bend and the CG was being brought closer to the TH. The action where the athlete is hanging and then flexes the hips, brings the feet to the hands, followed by an extension of the hips and trunk as the CG is raised vertically describes a move commonly used in gymnastics called a kip when used on the rings or high bar. During the flexion phase of the hips, centrifugal force pulls down on the hands during the kip on the high bar, and similarly on the pole [3]. When watching the vaulter during the Hang-Swing phase it almost appears that the vaulter is delaying, however during the Pole Plant, Take-Off, Hang-Swing, and Swing-Tuck there is a continual application of forces to transfer the energy of the approach run, take-off jump, and the flexion of the hips and trunk into the pole.

During the Hang-Swing and Swing-Tuck phases there is a transition from linear kinetic energy to strain energy in the pole. It appears at times that the vaulter delays as he goes through the Hang-Swing phase, however he should be constantly adding energy to the system through the flexion of the hips and trunk, and eventually the extension of the hips and trunk, and push-off. After MPB, the pole begins to return to a straight position returning energy that has been put into the pole during the Hang-Swing and Swing-Tuck phases. More energy is added to the system through the Extension of the hips and trunk as the pole is straightening. This is similar to a diver who depresses the board and as the board is pushing the diver upwards the diver pushes with his legs downward and adds additional energy to the system.

As the pole straightens, the pole tends to throw the vaulter horizontally into the bar, as well as upwards. Although the direction of the force vector of the pole straigtening is outward in the direction of the pole cord the configuration of the vaulter's body is such that the body tends to drop unless the vaulter can work against that tendency. Vaulters who direct their feet towards the bar during the extension phase will experience a dropping of their legs into the bar due to the straightening of the pole. This lowers the peak height of the CG. It is therefore necessary for the vaulter, during the extension phase, to direct their feet upwards, but in front of the bar. The tendency for the pole to throw the vaulter into the bar, is nullified by the extension in front of the bar so that the vaulter projects more vertically upwards (Figure 7). This is one of the major problems with younger vaulters, but was still evident in these experienced college vaulters. Experienced vaulters practice exaggerated rock-back motions during short approaches, which almost look like they are trying to do back somersaults. Some vaulters actually do a back somersault and leave go of the pole landing on their feet in the pit.

Pole release occurred in front of the top of the box by 0.16m and 0.08m in front of the pole vertical position (Figure 5). The position of the CG at the peak height was at X:0.755, Y:5.643. The angle between the TH at pole release and the CG at the peak was 48.3°, and the distance between the two was 1.41 m. If the angle was increased to 60°, the vertical push off distance would increase from 1.053 m to 1.23 m, and the HP would have increased to 5.82 m, over 19 feet.

The current data from this study of collegiate class vaulters should contribute to and serve as a database for coaches to improve their coaching by monitoring many of these parameters among their vaulters with the objective of enhancing the performance of the parameter. For researchers, this data may be used for comparative purposes with future studies, and may form the basis for continued research.

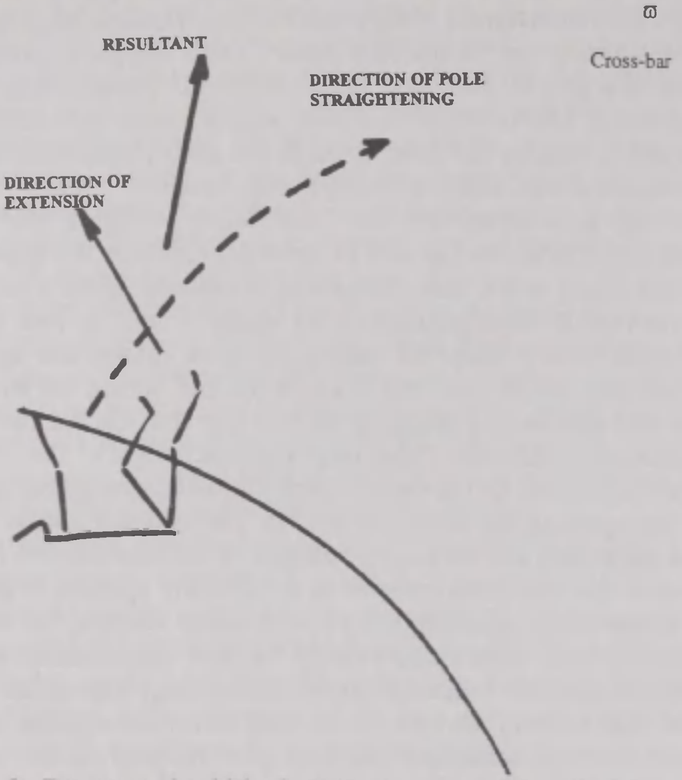

Figure 7. Extension should be in a direction away from the cross-bar to counter the effect of the straightening pole

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PHYSICAL GROWTH AND MATURATION RELATED VARIATION IN YOUNG MALE SOCCER ATHLETES

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ABSTRACT

The present study describes the somatic characteristics and sport-related fitness of 112 Portuguese young male soccer players (10.9–18.5 years of age). Anthropometry included the variables needed to estimate Heath-Carter *somatotype* and *index of androgyny*. Stage of *pubic hair* development was evaluated at clinical examination. *Motor fitness* was assessed as endurance, velocity, agility, strength and flexibility. In addition, two specific soccer tests were adopted: *Soccer Wall Pass* and *Soccer Dribble*. Data show progressive gains in body size from infantiles (11–12 yr) to juniors (17–18 yr), as well as an increase in almost all sport-related fitness measurements. The effect of chronological age on body size was evident within infantiles and initiates (13–14 yr), while the effect of maturational status on motor performance was only significant within initiates. Initiates who are at PH2 are older by 0.7 years but shorter than infantiles who are in PH3. The reduced variation in older boys reflects approaching maturity in late adolescence so that size and physique differences between boys of contrasting maturity status are reduced.

Key words: young athletes, growth status, maturation, motor performance, soccer

INTRODUCTION

The variation of body size, morphology and maturational characteristics is reasonably well documented in the context of motor performance [1]. These associations have a decisive effect on long-term preparation, particularly on sport specialization and selection [5, 6].

In the case of boys, early maturing subjects tend to be taller, heavier and, at the same time, they obtain better results in strength, speed and muscle power tests when compared to "on time" and late maturing peers [2, 7]. It is not surprising that, particularly during post puberty years and in sports such as soccer, there are no late maturing athletes among the elite of 13–16 year-old players [8, 9].

In Portugal, there are very few studies (according to sport modality) reporting the variation of morphology and body size related to chronological age controlling for maturation.

The present study considers body size and maturity status of soccer players aging from 10.9 to 18.6 years to establish comparisons: a) between players of different age-groups, b) between younger and older subjects within the same age-groups, c) between players of the same age-groups but at different maturity stages.

MATERIALS AND METHODS

The sample of the present study is composed of 112 soccer players from Portuguese Midlands. They were grouped in four categories: a) infantiles (IF): 11–12 years, n=29; b) initiates (IC): 13–14 years, n=37; c) juveniles (JV): 15–16 years, n=29; d) juniors (JN): 17–18 years, n=17.

The somatic variables included measurements needed to determine somatotype [3], androgyny index (3 x biacromial diameter — bicristal diameter), an estimation of somatic virility [11]. The pubic hair stages were evaluated according to the criteria published by Tanner [10].

Sport-motor fitness was assessed on the basis of the following tests results: 20-meter shuttle-run (PACER — Progressive Aerobic Cardiovascular Endurance Run), 12-minute run, 25-meter dash, agility shuttle-run (10x5 meters), standing long jump, vertical jump, 60-second sit-ups, hand grip dynamometer and sit-and-reach. The tests suggested by Kirkendall *et al.* [4], namely *Soccer Wall Pass Test* and the *Soccer Dribble Test*, were also adopted.

Means and standard deviations were determined. Afterwards, within each age-group (infantiles, initiates, juveniles and juniors), comparisons between younger and older athletes were performed adopting *t-test.* ANCOVA, with age as covariate, was used to test the effect of maturational status on somatic variables, motor performance and soccer skills, separately for each age-group.

RESULTS AND DISCUSSION

Variation between age-groups

As expected, body size increases across age (see **Table 1**). In a study carried out among European and Latin American elite players, Malina *et al.* [8] showed that, by the end of adolescence, soccer players have a larger body bulk relatively to stature, based on US normative values.

Given the subcutaneous fat values (**Table 1**), it is likely that the weight is due to the musculoskeletal structures. The average somatotype of infantiles, initiates, juveniles and juniors are located in the balanced mesomorph category (**Figure 1**). At least in the soccer case, the hypothesis suggested by Carter & Heath [3] seems to be confirmed: young athletes have a similar, or even identical, physical structure to adult athletes of the same sport modality.

Data also confirm a progressive improvement in all sport-related fitness tests, including passing and dribbling, from infantiles through juniors. The exception seems to be the stagnation of the maximum aerobic capacity and sit-ups from juveniles to juniors.

Table 1. Morphology, somatotype and sport-motor fitness of young soccer players, according to age groups. ($\overline{X} \pm SD$)

	Infantiles (n=29)	Initiates (n=37)	Juveniles (n=29)	Juniors (n=17)
Age (years)	12.0±0.5	13.9±0.6	16.1±0.5	17.8±0.5
Stature (cm)	145.6±5.3	164.0±9.3	172.5±5.1	175.9±6.0
Body weight (kg)	37.8±4.8	52.5±8.3	63.8±5.8	71.0±4.8
Biacromial diameter (cm)	32.6±1.5	36.5±2.1	39.8±1.7	40.8±1.8
Bicristal diameter (cm)	22.5±1.7	25.5±1.6	26.5±1.1	27.1±0.9
Humerus diameter (cm)	5.8±0.5	6.6±0.4	6.9±0.4	7.0±0.3
Femur diameter (cm)	8.9±0.6	9.6±0.5	9.7±0.4	10.0±0.3
Tensed upper arm circumference (cm)	22.4±1.8	25.6±1.8	28.5±1.8	30.9±1.7
Calf circumference (cm)	30.1±1.9	33.8±2.4	37.9±1.9	37.9±1.9
Triceps skinfold (mm)	10.3±3.9	10.2±3.2	8.2±2.1	11.3±3.5
Subscapular skinfold (mm)	6.7±3.2	7.9±2.2	8.4±1.6	10.9±2.6
Suprailiac skinfold (mm)	9.7±6.4	10.8±3.7	10.9±3.4	11.7±3.2
Calf skinfold (mm)	9.2±3.1	9.9±3.9	7.1±1.5	7.8±2.0
Androgyny índex (#)	75.19±3.64	84.11±5.42	92.88±4.63	95.22±5.23
Sum of skinfolds (mm)	35.9±15.0	38.8±11.3	34.6±7.0	41.7±9.1
Endomorphy	3.09±1.31	3.04±0.95	2.83±0.68	3.32±0.82
Mesomorphy	4.35±0.93	4.33±0.91	4.46±0.86	4.93±0.85
Ectomorphy	3.27±0.93	3.59±1.03	3.06±0.70	2.71±0.80
PACER (#)	65.1±14.2	87.4±12.8	96.3±9.7	96.7±13.1
12-min run (m)	2451±145	2630±258	2760±252	–
25-meter dash (sec)	4.85±0.26	4.48±0.21	3.97±0.19	3.75±0.14
Agility, 10x5 m run (sec)	18.20±1.65	17.13±1.34	16.93±0.91	–
Standing long jump (cm)	162.0±17.7	185.8±24.6	209.9±16.2	217.8±10.1
Vertical jump (cm)	28.0±5.6	33.8±7.6	43.9±6.4	–
60-second sit-ups (#)	44.0±9.8	46.8±6.7	55.5±6.8	55.5±4.9
Hand grip strength test (kg)	25.1±3.5	34.7±5.4	42.6±7.3	46.3±5.0
Sit-and-reach (cm)	15.2±4.9	13.7±6.0	15.5±8.2	20.8±8.2
Soccer wall pass test (#)	14.1±3.0	16.7±3.5	17.1±2.1	21.0±2.8
Dribble (sec)	11.48±0.96	11.06±0.82	10.68±0.86	10.23±0.54

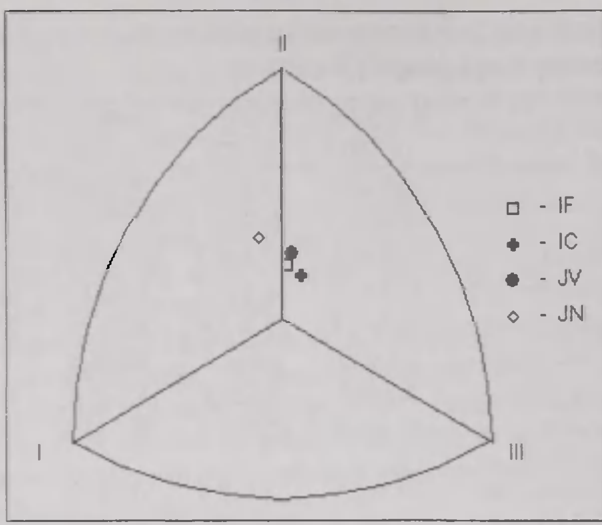

Figure 1. Somatocharts of young soccer players: infantiles (**IF**), initiates (IC), juveniles (JV) and juniors (JN).

Age-related variation within each age-group

Comparisons between 1st and 2nd year athletes in each age-group show that in both juveniles and juniors group differences tend to fade, not only in terms of body size variables but also regarding motor variables (**Table 3**). The same does not apply to infantiles and initiates (**Table 2**).

The 1st year infantile tends to be shorter (–4.8cm) and less fit, particularly in agility shuttle-run and vertical jump tests (**Table 2**). The greater discrepancies between 1st and 2nd year athletes were found among initiates. Younger players are shorter (–9.8 cm), leaner (–7.9kg), have a narrower bone structure (in the trunk as well as in the limbs) and are less fit in several categories: maximum aerobic capacity, velocity, standing long jump and hand grip strength.

In addition to age-related effect within each age-group, it is of interest to examine maturation-related variance due to differences in the time of occurrence and tempo (duration) of the pubertal growth spurt.

Table 2. Descriptive statistics and t-test to examine the effect of chronological age on physical structure, motor performance and soccer skills within Infantiles (n= 29) and Initiates (n=37).

	Infantiles			Initiates		
	IF1 n=14	IF2 n=15	p	IC1 n=18	IC2 n=19	p
Age (years)	11.5	12.4		13.4	14.4	
Stature (cm)	143.1	147.9	**	159.0	168.8	**
Body weight (kg)	37.5	38.0	n.s.	48.4	56.3	**
Biacromial diameter (cm)	32.5	32.7	n.s.	35.8	37.2	*
Bicristal diameter (cm)	22.4	22.7	n.s.	25.0	26.0	*
Humerus diameter (cm)	5.8	5.9	n.s.	6.4	6.8	**
Femur diameter (cm)	8.9	8.9	n.s.	9.4	9.7	*
Tensed upper arm circumference (cm)	22.3	22.5	n.s.	25.2	25.9	n.s.
Calf circumference (cm)	29.9	30.3	n.s.	33.1	34.5	*
Triceps skinfold (mm)	11.0	9.7	n.s.	11.2	9.4	n.s.
Subscapular skinfold (mm)	7.4	6.1	n.s.	8.1	7.7	n.s.
Suprailiac skinfold (mm)	11.1	8.3	n.s.	11.5	10.1	n.s.
Calf skinfold (mm)	9.4	9.0	n.s.	10.7	9.2	n.s.
Androgyny index (#)	74.8	75.6	n.s.	82.6	85.6	n.s.
Sum of skinfolds (mm)	39.0	33.0	n.s.	41.5	36.3	n.s.
PACER (#)	60.4	69.6	n.s.	81.6	93.0	**
12-min run (m)	2460	2444	n.s.	2666	2597	n.s.
25-meter dash (sec)	4.94	4.75	n.s.	4.58	4.37	**
Agility, 10x5 m (sec)	18.55	17.87	*	17.22	17.03	n.s.
Standing long jump (cm)	153.2	170.2	n.s.	173.9	197.0	**
Vertical jump (cm)	26.6	29.3	**	32.4	35.0	n.s.
60-second sit-ups (#)	41.1	46.7	n.s.	45.8	47.8	n.s.
Hand grip strength test (kg)	24.1	26.0	n.s.	31.5	37.7	**
Sit-and-reach (cm)	17.4	13.1	**	14.9	12.6	n.s.
Soccer wall pass test (#)	13.4	15.0	n.s.	15.7	17.7	*
Dribble (sec)	11.64	11.31	n.s.	11.13	10.99	n.s.

** ($p \leq 0.01$), * ($p \leq 0.05$), n.s. (not significant)

Table 3. Descriptive statistics and t-test to examine the effect of chronological age on physical structure, motor performance and soccer skills within Juveniles (n= 29) and Juniors (n=17).

	Juveniles			Juniors		
	JV1 n=7	JV2 n=22	p	JN1 n=9	JN2 n=8	p
Age (years)	15.4	16.4		17.4	18.3	
Stature (cm)	172.3	173.2	n.s.	175.4	179.2	n.s.
Body weight (kg)	61.6	64.5	n.s.	70.1	72.3	n.s.
Biacromial diameter (cm)	39.8	39.9	n.s.	40.9	40.6	n.s.
Bicristal diameter (cm)	26.5	26.6	n.s.	26.8	27.6	n.s.
Humerus diameter (cm)	6.9	6.9	n.s.	7.0	7.0	n.s.
Femur diameter (cm)	9.7	9.7	n.s.	10.0	10.1	n.s.
Tensed upper arm circumference (cm)	27.2	28.9	**	30.7	31.1	n.s.
Calf circumference (cm)	34.8	35.9	n.s.	38.0	37.8	n.s.
Triceps skinfold (mm)	7.7	8.4	n.s.	11.7	10.7	n.s.
Subscapular skinfold (mm)	7.9	8.6	n.s.	11.7	9.7	n.s.
Suprailiac skinfold (mm)	9.6	11.3	n.s.	12.4	10.7	n.s.
Calf skinfold (mm)	7.4	7.0	n.s.	7.4	8.3	n.s.
Androgyny index (#)	92.8	93.1	n.s.	95.9	94.3	n.s.
Sum of skinfolds (mm)	32.6	35.2	n.s.	43.2	39.3	n.s.
PACER (#)	91.0	98.1	n.s.	94.9	99.5	n.s.
12-min run (m)	2634	2800	n.s.	–	–	n.s.
25-meter dash (sec)	4.07	3.94	n.s.	3.77	3.71	n.s.
Agility, 10x5 m (sec)	16.95	16.92	n.s.	–	–	n.s.
Standing long jump (cm)	204.7	211.5	n.s.	221.7	212.0	n.s.
Vertical jump (cm)	41.6	44.7	n.s.	–	–	n.s.
60-second sit-ups (#)	56.8	55.0	n.s.	54.1	52.7	n.s.
Hand grip strength test (kg)	40.7	43.2	n.s.	42.9	43.4	n.s.
Sit-and-reach (cm)	14.0	16.0	n.s.	18.8	21.8	n.s.
Soccer wall pass test (#)	17.09	17.29	n.s.	22.0	21.7	n.s.
Dribble (sec)	10.79	10.65	n.s.	10.13	10.39	n.s.

** ($p \leq 0.01$), * ($p \leq 0.05$), n.s. (not significant)

Maturation-related variation within each age-group

The distribution of athletes according to the different stages of pubic hair within each age-group is shown in **Table 4**. Infantiles are rated between stage 1 and 3, initiates between stage 2 and 4, juveniles between stage 4 and 5, while all juniors are classified in stage 5. According to mode location (largest portion within each group), players in the 1st year of infantiles are pre-pubertal, puberty starts during the 2nd year of infantiles and lasts until juveniles.

With the exception of juniors, statistically significant differences in terms of height are observed in all age-groups (see **Tables 5** and **6**). For body weight, the effect of maturation is significant among initiates and juveniles. Skeletal robustness, given by the limbs and trunk transversal size, accounts for significant differences only among initiates (**Table 5**). The juveniles group, on the other hand, registers a significant effect of maturation over appendicular muscularity, given by the upper arm and calf circumferences (**Table 6**).

Table 4. Sample distribution according to stages of sexual maturation given by pubic hair (n=112).

	Maturation stage (pubic hair)					
Group	PH1	PH2	PH3	PH4	PH5	Total
IF1	8	6	–	–	–	14
IF2	1	9	5	–	–	15
IC1	–	5	8	5	–	18
IC2	–	–	4	15	–	19
JV1	–	–	–	6	1	7
JV2	–	–	–	11	11	22
JN1	–	–	–	–	9	9
JN2	–	–	–	–	8	8
Total	**9**	**20**	**17**	**37**	**29**	**112**

Only among the initiates (**Table 5**) is possible to observe a significant effect of maturity status over physical capacities, particularly in 12-minutes run, 25-meters dash, standing long jump, vertical jump and hand grip strength.

In all age-groups, data seems to suggest that motor mastery (wall pass and dribbling) does not depend on maturity status.

Figure 2 shows the stature of subjects according to age-groups and pubic hair stages. Initiates rating at stage 2, although being 0.7 years older than infantiles at pubic hair stage 3, are 2.5 cm shorter. In addition, initiates at stage 4, despite being 1.7 years younger than juvenile players at the same stage, are only 1.5 cm shorter.

In other words, the group of initiates seems shows the greatest variance in body size, given by the height and body mass (see **Table 1**). This variance is partially accounted for the maturity status since late maturing initiates are shorter than early maturing infantiles and, simultaneously, initiates rating at stage 4 are practically of the same height as juveniles at the same sexual maturational stage.

Table 5. Descriptive statistics and significance tests to examine the effect of maturation on physical structure, motor performance and soccer skills, separately for infantiles (n=29) and initiates (n=37).

	Infantiles (IF)				Initiates (IC)			
	PHI n=9	PH2 n=15	PH3 n=5	p	PH2 n=5	PH3 n=12	PH4 n=20	p
Age (years)	11.6	12.0	12.5		13.2	13.7	14.2	
Stature (cm)	142.7	145.2	152.0	**	149.5	161.4	169.3	**
Body weight (kg)	36.6	37.6	40.4	n.s.	43.2	48.7	57.0	**
Biacromial diameter (cm)	32.2	32.5	33.5	n.s.	34.3	35.9	37.5	**
Bicristal diameter (cm)	22.2	22.5	23.4	n.s.	23.7	25.1	26.2	**
Humerus diameter (cm)	5.7	5.8	6.0	n.s.	6.4	6.4	6.8	*
Femur diameter (cm)	8.8	8.9	9.2	n.s.	9.3	9.4	9.8	*
Tensed upper arm circumference (cm)	22.1	22.5	22.6	n.s.	24.5	24.9	26.2	*

	Infantiles (IF)				Initiates (IC)			
	PH1 n=9	PH2 n=15	PH3 n=5	p	PH2 n=5	PH3 n=12	PH4 n=20	p
Calf circumference (cm)	29.8	30.1	30.3	n.s.	31.6	32.9	34.9	n.s.
Triceps skinfold (mm)	10.2	10.6	9.6	n.s.	13.8	10.0	9.5	**
Subscapular skinfold (mm)	6.1	7.4	5.8	n.s.	8.0	7.6	8.1	n.s.
Suprailiac skinfold (mm)	9.0	10.9	7.0	n.s.	13.2	10.3	10.5	n.s.
Calf skinfold (mm)	8.6	9.5	9.4	n.s.	12.0	10.0	9.4	n.s.
Androgyny index (#)	74.5	75.0	77.1	n.s.	79.3	82.7	86.2	**
Sum of skinfolds (mm)	33.9	38.5	31.8	n.s.	47.0	37.8	37.4	n.s.
PACER (#)	61.3	64.9	72.8	n.s.	80.4	86.6	89.7	n.s.
12-min run (m)	2443	2451	2476	n.s.	2553	2606	2710	*
25-meter dash (sec)	4.89	4.85	4.76	n.s.	4.74	4.55	4.37	**
Agility, 10x5 m run (sec)	19.00	17.93	17.55	n.s.	17.31	17.09	17.02	n.s.
Standing long jump (cm)	152.3	166.0	166.5	n.s.	162.8	176.6	197.0	**
Vertical jump (cm)	26.8	28.0	27.7	n.s.	26.8	32.8	36.6	*
60-second sit-ups (#)	39.9	44.5	49.8	n.s.	43.8	45.9	48.2	n.s.
Hand grip strength test (kg)	24.2	25.3	27.4	n.s.	28.1	32.5	37.6	**
Sit-and-reach (cm)	16.8	15.3	12.0	n.s.	13.4	12.8	14.4	n.s.
Soccer wall pass test (#)	14.8	13.9	13.6	n.s.	13.8	18.1	16.6	n.s.
Dribble (sec)	11.63	11.41	11.42	n.s.	11.73	11.03	10.91	n.s.

** ($p \leq 0.01$), * ($p \leq 0.05$), n.s. (not significant), PH1 (stage 1 of pubic hair), PH2 (stage 2 of pubic hair), PH3 (stage 3 of pubic hair), PH4 (stage 4 of pubic hair).

Table 6. Descriptive statistics and significance tests to examine the effect of maturation on physical structure, motor performance and soccer skills for juveniles (n=29).

	Juveniles (JV)			Juniors (JN)
	PH4 n=17	PH5 n=12	p	PH5 n=17
Age (years)	15.9	16.3		17.8
Stature (cm)	170.8	175.0	*	175.9
Body weight (kg)	60.7	68.2	**	71.0
Biacromial diameter (cm)	39.5	40.3	n.s.	40.8
Bicristal diameter (cm)	26.4	26.7	n.s.	27.1
Humerus diameter (cm)	6.8	7.1	n.s.	7.0
Femur diameter (cm)	9.6	9.8	n.s.	10.0
Tensed upper arm circumference (cm)	27.8	29.5	**	30.9
Calf circumference (cm)	34.8	36.9	**	37.9
Triceps skinfold (mm)	7.9	8.7	n.s.	11.3
Subscapular skinfold (mm)	7.9	9.1	*	10.9
Suprailiac skinfold (mm)	9.9	12.3	n.s.	11.7
Calf skinfold (mm)	7.2	6.9	n.s.	7.8
Androgyny index (#)	92.0	94.1	n.s.	95.2
Sum of skinfolds (mm)	32.9	36.9	n.s.	41.7
PACER (#)	93.8	99.9	n.s.	96.7
12-min run (m)	2708	2835	n.s.	–
25-meter dash (sec)	4.00	3.93	n.s.	3.75
Agility, 10x5 m run (sec)	16.90	16.96	n.s.	–
Standing long jump (cm)	207.8	212.8	n.s.	217.8
Vertical jump (cm)	44.9	42.5	n.s.	–
60-second sit-ups (#)	56.0	54.7	n.s.	55.5
Hand grip strength test (kg)	40.9	44.9	n.s.	46.3
Sit-and-reach (cm)	15.1	16.1	n.s.	20.8
Soccer wall pass test (#)	17.2	17.0	n.s.	21.0
Dribble (sec)	10.80	10.55	n.s.	10.23

** ($p \leq 0.01$), * ($p \leq 0.05$), n.s. (not significant), PH4 (stage 4 of pubic hair), PH5 (stage 5 of pubic hair).

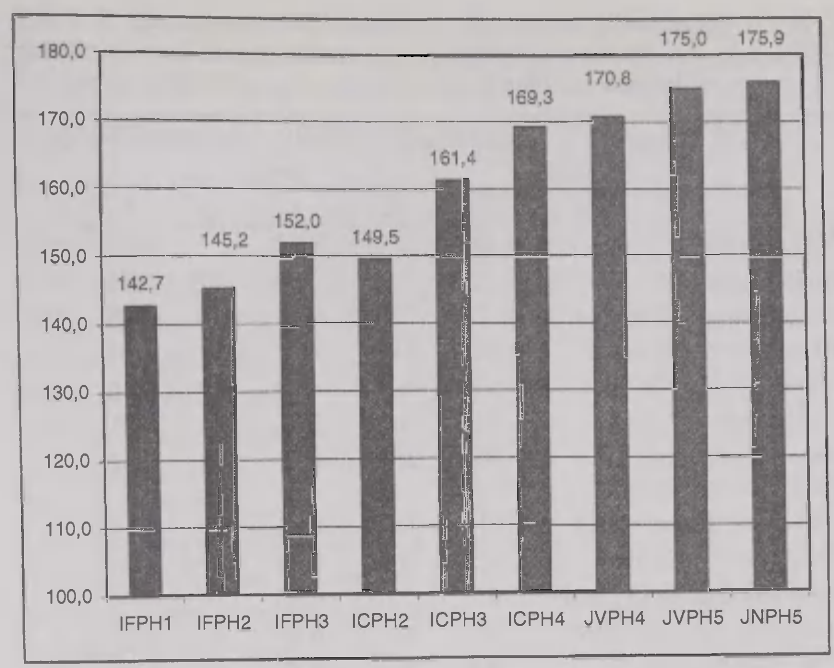

Figure 2. Mean values for stature by age-groups (IF: infantiles, IC: initiates, JV: Juveniles, JN: juniors) and pubic hair (PH1-PH5): IFPH1 (n=9, 11.6 years), IFPH2 (n=15, 12.0 years), IFPH3 (n=5, 12.5 years), ICPH2 (n=5, 13.2 years), ICPH3 (n=12, 13.7 years), ICPH4 (n=20, 14.2 years), JVPH4 (n=17, 16.0 years), JVPH5 (n=12, 16.3 years), JNPH5 (n=17, 17.8 years).

Age stability of physical structure, motor performance and skill mastery

Based on a 2-year follow-up study of 22 infantiles and 19 initiates (first assessment in 2000/01), it was possible to establish inter-age stability coefficients for each variable (**Tables 7** and **8**).

Table 7. Mean values at moment 1 (2000/2001) and moment 2 (2002/2003), inter-age bivariate correlations and partial correlations controlling for age among infantiles at baseline (n=22).

	Infantiles 2000/01 — Initiates 2002/03 (n=22)					
	IF	IC	r	p	r'	p
Stature (cm)	144.9	159.3	0.88	**	0.86	**
Body weight (kg)	37.8	49.0	0.74	**	0.76	**
Biacromial diameter (cm)	32.6	35.0	0.61	**	0.63	**
Bicristal diameter (cm)	22.5	24.9	0.90	**	0.91	**
Humerus diameter (cm)	5.8	6.3	0.69	**	0.85	**
Femur diameter (cm)	8.9	9.4	0.83	**	0.83	**
Tensed upper arm circumference (cm)	22.4	25.5	0.55	**	0.57	**
Calf circumference (cm)	30.1	34.1	0.85	**	0.85	**
Triceps skinfold (mm)	10.3	9.6	0.64	**	0.60	**
Subscapular skinfold (mm)	6.7	7.0	0.65	**	0.65	**
Suprailiac skinfold (mm)	9.7	9.4	0.51	*	0.45	*
Calf skinfold (mm)	9.2	9.8	0.89	**	0.88	**
Androgyny index (#)	74.8	80.8	0.49	*	0.51	*
Sum of skinfolds (mm)	36.9	35.7	0.73	**	0.69	**
Endomorphy	3.09	2.79	0.64	**	0.57	**
Mesomorphy	4.45	4.66	0.78	**	0.74	**
Ectomorphy	3.27	3.35	0.66	**	0.55	**
PACER (#)	66.2	84.3	0.82	**	0.76	**
25-meter dash (sec)	4.88	4.32	0.57	**	0.50	*
Standing long jump (cm)	159.0	182.1	0.76	**	0.70	**
60-second sit-ups (#)	43.0	52.0	0.76	**	0.73	**
Hand grip strength test (kg)	25.2	30.5	0.68	**	0.60	**
Sit-and-reach (cm)	15.2	13.0	0.81	**	0.76	**
Soccer wall pass test (#)	14.8	20.8	0.50	*	0.54	**
Dribble (sec)	11.81	10.96	0.70	**	0.70	**

** ($p \leq 0.01$), * ($p \leq 0.05$)

Table 8. Mean values at moment 1 (2000/2001) and moment 2 (2002/2003), inter-age bivariate correlations and partial correlations controlling for age among initiates at baseline (n=19).

	Initiates 2000/01 — Juveniles 2002/03 (n=22)					
	IC	JV	r	p	r'	p
Stature (cm)	162.2	170.6	0.80	**	0.79	**
Body weight (kg)	50.8	60.1	0.60	**	0.60	**
Biacromial diameter (cm)	36.5	38.4	0.50	*	0.42	**
Bicristal diameter (cm)	25.5	26.9	0.81	**	0.82	**
Humerus diameter (cm)	6.6	6.7	0.74	**	0.91	**
Femurus diameter (cm)	9.6	9.7	0.82	**	0.82	**
Tensed upper arm circumference (cm)	25.6	28.2	0.40	n.s.	0.40	n.s.
Calf circumference (cm)	33.8	35.8	0.73	*	0.68	**
Triceps skinfold (mm)	10.2	9.6	0.63	**	0.63	**
Subscapular skinfold (mm)	7.9	8.9	0.41	n.s.	0.41	n.s.
Suprailiac skinfold (mm)	10.9	11.4	0.54	*	0.53	*
Calf skinfold (mm)	9.9	8.4	0.37	n.s.	0.37	n.s.
Androgyny index (#)	84.5	88.4	0.43	*	0.35	n.s.
Sum of skinfolds (mm)	37.3	38.3	0.31	n.s.	0.31	n.s.
Endomorphy	3.05	2.99	0.36	n.s.	0.36	n.s.
Mesomorphy	4.30	4.47	0.81	**	0.81	**
Ectomorphy	3.59	3.36	0.62	**	0.63	**
PACER (#)	87.2	95.1	0.66	**	0.68	**
25-meter dash (sec)	4.45	3.91	0.38	n.s.	0.51	*
Standing long jump (cm)	182.8	210.8	0.43	*	0.45	*
60-second sit-ups (#)	47.6	54.1	0.66	**	0.69	**
Hand grip strength test (kg)	34.3	41.3	0.32	n.s.	0.34	n.s
Sit-and-reach (cm)	14.2	17.32	0.57	*	0.59	*
Soccer wall pass test (#)	17.0	21.4	0.20	n.s.	0.29	n.s.
Dribble (sec)	11.13	10.37	0.62	**	0.61	**

** ($p \leq 0.01$), * ($p \leq 0.05$)

Coefficients range between 0.51 (suprailiac skinfold) and 0.90 (bicristal diameter), for the infantiles-initiates period, and 0.37 (calf skinfold) and 0.81 (bicristal diamater), for the initiates-juveniles interval.

The measurement technical error (e) and the reliability coefficient (R) for indicators with lower inter-age coefficients was (e=0.92, R= 0.98) and (e=0.76, R=0.97), respectively for suprailiac and calf skinfolds. The quality of data suggested by the measurement technical error (e) and the reliability coefficient do not contradict the idea of less fatness inter-age stability comparatively to osteo-transverse measurements.

Height seems to be more stable than body mass in the two analyzed groups. Among the somatotype components, mesomorphiy is the most stable component. Endomorphy is influenced by fatness variation and ectomorphy reflects not only height variations but also, and particularly, body mass variations.

The magnitude of the infantiles-initiates coefficients on motor tests (performance and skills) is consistently higher than the coefficients of the interval initiates-juveniles. The over emphasis of morphology and fitness variables to support sport selection and/or sport exclusion among infantiles should be avoided, since substantial changes would occur in the interval initiates-juvenils (where the athletes move from stage 3 to 4 of pubic hair).

According to Malina *et al.* [7], subjects at pubic hair stage 3 tend to be at the peak of the pubertal growth spurt. The peak height velocity tends to occur between stage 3 and 4, whereas weight peak velocity occurs a little later. These asynchronisms should not be ignored in the choice of the best indicators to evaluate young athletes. Since jumps and velocity are important features of athletic-related fitness, sport selection at the infantiles based on these measurements might leave out players that later come to be the most fit in these traits.

Taking into account that data included some intra-group age variation, we decided to establish inter-age correlation coefficients by removing age spurious effect. That is to say that the authors controlled the possibility of the rankings among group be attributed to the fact that they are either older or younger, a condition that would be maintained after two years. As shown in **Tables** 7 and **8**, partial correlations assume magnitudes closed to bivariate coefficients.

CONCLUSIONS

Athletes from different age-groups show distinct morphological and sport-motor fitness profiles. Regarding body size, the differences between juvenile and junior players are particularly detected in body weight. In such traits as the maximum aerobic capacity (PACER) and abdominal strength resistance (sit-ups) there are no substantial differences between athletes aged 15/16 and 17/18.

Soccer players are included in the balanced mesomorph category, although a slight migration towards northwest of the junior athletes.

The greater number of differences between 1st and 2nd year athletes occurs among initiates. Infantiles show differences between 1st and 2nd year athletes in some motor performance measurements.

It is likely that the better results obtained in shuttle-run and vertical jump tests by 12-year-old players, compared to 11-year-old peers, can be attributed to their own sport experience since it is known that potential progression is higher at the beginning of sport training.

Although this is not a longitudinal study and taking into account the distribution of subjects according to sexual maturation stages, the pubertal growth spurt seems to occur between the infantiles 2nd year and the juveniles 1st year.

There is a considerable overlap between the morphological and functional profile of early maturing infantiles and the late maturing initiates.

Sexual maturation establishes a significant effect over morphological and motor performance variables particularly in initiates, where it was identified a greater data variance in traits such as body weight and height.

The period raging from initiates to juveniles shows less inter-age stability, which causes the prognosis to be rather fallible when made before the end of age 15 to 16. Therefore, the assessment of the athletic potential of young soccer players, for sport selection and exclusion purposes, should not be made final before juveniles.

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HORMONAL RESPONSE TO MAXIMAL ROWING DURING HEAVY TRAINING IN MALE ROWERS

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ABSTRACT

The aim of this study was to investigate the hormonal response at rest and during maximal 2000 metre rowing ergometer test in 12 highly trained male rowers before and after three week heavy training period. Venous blood samples were obtained before, immediately after and after 30 min of recovery of the rowing performance test. Cortisol, insulin, glucose and creatine kinase were measured. Mean training time was about 17.5 $h.week^{-1}$ during the heavy training period. 2000 metre rowing ergometer performance parameters were not different between tests. Resting cortisol and glucose values were not different between tests. Three week heavy training period induced significant reductions and increases in resting insulin and creatine kinase values, respectively. A significantly ($p<0.05$) higher maximal exercise-induced increase of the creatine kinase was measured after heavy training period. The responses of cortisol and insulin were unchanged after heavy training period. Our findings indicate that the first sign of decreased adaptivity in athletes is a decreased resting level of insulin; and an increased resting level and higher maximal exercise-induced increase in creatine kinase concentration.

Key words: hormones, heavy training, rowing

INTRODUCTION

The purpose of athletic training is to improve performance. A dose-response relationship has been demonstrated between training volume and performance in athletes [6,10]. Athletic training consists of a well programmed system of physical stress, requiring daily training or in some instances even multiple daily workouts [6]. Usually, high load training phases are followed with lower training load to allow to recover from stressful training [7]. Induced training stimulus will cause a disturbance in cellular homeostasis [6], and overtraining is attained when training load and the associated disturbances in cellular homeostasis are not matched with adequate recovery [10]. The evaluation of the state of an athlete, e.g. of current trainability and of the diagnosis of possible overload, appears to be one of the most complicated tasks in sports science [6,12]. Different biochemical and psychological markers have been used to monitor the state of an athlete during training [6,10].

The acute responses in the endocrine system during physical stress are related to the intensity and duration of the specific exercise stimulus as well as to the physical condition of athletes [4,5]. Assessment of circulating concentrations of hormones during prolonged physical stress and/or training has also received considerable attention due to its implications for general adaptive mechanisms and for physical conditioning [10]. Hormonal mechanisms most assuredly help mediate both short-term homeostatic control and long-term cellular adaptations to any type of stress are imposed on man.

The purpose of this study was to examine hormone resting levels and responses to maximal rowing ergometer test before and after heavy training period in highly trained male rowers.

METHODS

Subjects

Twelve healthy and well-trained national standard male rowers (age 20.5±3.0 years, height 1.88±0.06 m, body mass 87.1±8.3 kg, percent body fat 10.4±3.2%) volunteered to participate in the study. They had trained regularly for the last 6.1±1.0 years. The rowers were familiarized with the procedures before providing their consent to participate in the experiment as approved by the Medical Ethics Committee of the University of Tartu. The height (Martin metal anthropometer) and body mass (A&D Instruments Ltd, UK) of the participants were measured to the nearest 0.1 cm and 0.05 kg, respectively. Body composition was measured using a multi-frequency impedance analyzer (Multiscan 5000, Bodystat Ltd, UK).

Training schedule

The study was conducted during the preparatory period, where the main aim of training was the development of basic strength-endurance [9]. No symptoms of possible overtraining [12] were found at the start of the experimental period. The week before experimental period was one of moderate standardized training and six training sessions were completed during this week. The three week heavy training period was aimed to maximally overload the subjects [9,10]. In total, 12 training sessions were completed during every week of the exhaustive training period. The athletes trained six days a week. The training regimen of rowers was typical for this period of year [9], and consisted of 45% of high-volume low-intensity strength training aimed for the improvement of strength-endurance, 45% of extensive endurance training (running, swimming and/or ergometer rowing) aimed for the improvement of basic endurance and 10% of different kind of ball games (basketball and/or soccer).

Performance testing

Maximal 2000 metre rowing ergometer performance time was assessed before (Test 1) and immediately after (Test 2) the heavy training period on a wind resistance braked rowing ergometer (Concept II, Morrisville, USA) [6]. Performance testing sessions were carried out at the same time of the day (i.e., between 11.00 and 13.00 hours) and testing time was identical for each subject across both tests. The rowers were fully familiarized with the use of this apparatus. Power and stroke frequency were delivered continuously by the computer display of the rowing ergometer. Heart rate (HR) was recorded every 5 s (Sporttester Polar Vantage NV, Kempele, Finland) during rowing performance test. Venous blood samples were obtained before (PRE), immediately after (POST) and 30 min after (POST-30') rowing performance test.

Blood analysis

A 10 ml blood sample was obtained from an anticubital vein with the subject in the upright position [5]. The plasma was separated and frozen at –20°C for later analysis. Cortisol was measured in duplicate on Immulite 2000 (DPC, Los Angeles, USA). The inter- and intra-assay coefficients of variation were less than 5%. Insulin was determined by means of an immunoradiometric assay (ICN Micromedic System, USA) with an intra- and inter-assay CV of 4.5% and 12.2% at an insulin concentration of 6.6 $\mu IU.ml^{-1}$, respectively. Glucose was measured by means of the hexokinase/glucose 6-phosphate-dehydrogenase method by using a commercial kit (Boehringer Mannheim, Germany). Creatine kinase was measured by means of photometric method by using a commercial kit (Boehringer Mannheim, Germany). Samples from one individual were run on the same assay. Aliquots of whole blood were also analysed in quadruplicate for haematocrit at 12,000 $rev.min^{-1}$ for 5 min and for haemoglobin using a Lange (Germany) microanalyzer. Post-exercise changes in plasma volume were calculated using the formulae of Dill and Costill [2].

Statistical methods

Means and standard deviations (s) were determined. Repeated measures analyses of variance (ANOVA) were used to determine changes in measured rowing performance parameters over time. For blood data analysis obtained during rowing ergometer tests, the influence of blood sampling and testing times were examined by two-way ANOVA with repeated measures. Matched-paired student's t-test was used where *post-hoc* analysis was relevant. An alpha of 0.05 was adopted.

RESULTS

All subjects completed the study. Mean training time was about 100% higher during the heavy training period (17.5 $h.week^{-1}$) compared to the mean training time in the week before the heavy training period (9.3 $h.week^{-1}$). Subjects maintained their body mass and body fat values throughout the study period despite the high training load (data not shown). 2000 metre rowing ergometer performance parameters after heavy training period were not significantly changed (Table 1). The haematocrit and haemoglobin concentrations were found to have increased significantly immediately after rowing ergometer tests ($p<0.05$). However, no other statistically significant differences were noted in these measures in any of the assessed conditions (data not shown). Significant reductions ($p<0.05$) in plasma volume were only found immediately after the maximal rowing ergometer test in both testing times. These changes were –6.6±8.0% and –6.8±7.8% for the Test 1 and Test 2, respectively. No significant differences in plasma volume reductions immediately after maximal rowing ergometer test were observed between both exercise trials.

Cortisol and glucose were not different between tests at rest (Table 2). However, insulin and creatine kinase were lower and higher, respectively, after heavy training (Test 2) compared to the values obtained before the heavy training (Test 1). The maximal exercise-induced cortisol, insulin, glucose and creatine kinase values were higher immediately after both tests (Table 3). While cortisol, insulin and glucose values after both tests were similar. Creatine kinase was higher after heavy training compared to the corresponding value obtained before heavy training.

Table 1. Maximal rowing ergometer performance parameters before (TEST-1) and after (TEST-2) heavy training period in highly trained male rowers (mean ± SD).

Variable	TEST-1	TEST-2
Time (s)	384.5±13.7	384.9±12.0
Mean power (W)	397.5±42.3	395.6±37.5
Max HR (beats.min^{-1})	188.3±5.3	188.8±8.2
Mean HR (beats.min^{-1})	178.3±5.3	176.8±7.8

* Significantly different from TEST-2: $P<0.05$.

Table 2. Fasting cortisol, insulin, glucose and creatine kinase before (TEST-1) and after (TEST-2) three weeks of heavy training period (mean ± SD).

Variable	TEST-1	TEST-2
Cortisol (nmol.l^{-1})	561.5±99.8	549.9±90.8
Insulin (μIU.ml^{-1})	8.7±4.9	6.8±3.4*
Glucose (mmol.l^{-1})	4.9±0.5	4.6±0.5
Creatine kinase (U.l^{-1})	320.3±150.8	527.1±294.4*

* Significantly different from TEST-1; $P<0.05$.

Table 3. Cortisol, insulin, glucose and creatine kinase activity before (PRE), immediately after (POST) and 30 min after (POST-30') maximal 2000 metre rowing ergometer test before (TEST-1) and after (TEST-2) three weeks of heavy training period (mean ± SD).

	TEST-1	TEST-2
Cortisol ($nmol.l^{-1}$)		
PRE	405.8±132.2	423.3±79.9
POST	530.6±109.4*	500.8±134.5*
POST-30'	661.7±127.6*#	655.3±108.1*#
Insulin ($\mu IU.ml^{-1}$)		
PRE	10.9±6.4	11.9±5.8
POST	21.8±12.9*	24.3±12.8*
POST-30'	8.9±4.3*#	9.8±5.3*#
Glucose ($mmol.l^{-1}$)		
PRE	4.0±0.4	3.9±0.6
POST	8.0±1.2*	7.8±0.7*
POST-30'	4.6±1.0#	4.5±1.1#
Creatine kinase ($U.l^{-1}$)		
PRE	467.2±219.6	663.3±404.0 $
POST	543.3±248.3*	775.1±489.3* $
POST-30'	497.7±228.7#	699.1±413.4# $

* Significantly different from PRE; P<0.05.
# Significantly different from POST; P<0.05.
$ Significantly different from TEST-1; P<0.05.

DISCUSSION

The purpose of this study was to examine the effect of heavily increased training stress on rowing ergometer performance parameters; and on hormone concentrations before and after 2000 metre maximal rowing ergometer test in highly trained male rowers. In the present study, the heavy training stress was induced by a distinct increase in exercise volume with the exercise intensity remaining relative low throughout the study [6,9]. The results of this study indicate that heavy changes in training stress are best reflected by changes in resting insulin and creatine kinase, and maximal exercise-induced changes in creatine kinase values. While resting cortisol and maximal exercise-induced changes in cortisol concentration were not different as a result of heavily increased training period. In addition, no changes in rowing ergometer performance parameters were observed.

Exercise-induced hormone concentrations should be corrected by changes in plasma volume, as a decrease in plasma volume could increase the value. However, similarly to our recent study [5], the hormone concentrations reported are uncorrected for exercise-induced plasma volume alterations. Firstly, it may be the concentration of the hormone at the target tissues that is of importance, regardless of how the change in concentration is established [4]. Secondly, moving from the standing position prior to the exercise to a seated position during rowing exercise could have caused, independently of the exercise undertaken, a change in plasma volume due to haemodynamic redistribution of fluids [8]. Thirdly, the computed reductions in plasma volume values were not significantly different between three tests.

The decrease in resting insulin after three week heavy training period is in accordance with the results of other studies [1,11], who have demonstrated a significant decrease in anabolic activity during high load training phases. Indeed, the training load was higher than 1000 min per week during heavy training period, which is considered to be typical in high load training phases for highly trained rowers [9]. Increased resting cortisol level has usually been found during hard training stages [10] and could be regarded as an early sign of overtraining [6], while the reduced resting cortisol level appears to be a sign of an advanced overtraining [11]. In our study, we did not observe any changes in resting cortisol level as a result of heavy training period. Thus, the resting levels of anabolic and catabolic hormones of present study would suggest that the three week heavy training period was characterized with relatively high physical strain and had beneficial adaptive effects for highly trained male rowers.

It has been suggested that instead of a resting hormone levels, hormonal responses to maximal exhaustive exercise may provide better assessment of the changes in athletes adaptivity [11,12]. Accordingly, the main finding of this investigation was higher exercise-induced increase in creatine kinase after the maximal rowing ergometer test performed after the three week period of heavy training stress. These results together with no change in performance parameters would suggest that the aim of the heavy training period, to reach a state of short-term overreaching, was achieved.

The monitoring of the characteristics of training may allow an athlete to achieve the goal of specific training periods, while minimizing an undesired training outcome. The results of present study demonstrated that the used heavy load training programme had positive physiological effects for highly trained athletes. It has been suggested that hormonal indicators of overtraining have strength only in conjunction with a decrease in specific performance parameters and mood changes [3]. The hormonal results after heavy training stress in this study could be interpreted as the first indicators of the risk of the appearance of overtraining as no changes in performance parameters were observed. Further hard training would probably have caused an overtraining state with suppressed resting and exercise-induced cortisol levels and decreased performance in highly trained male rowers.

In conclusion, the results of present study suggest that the first signs of a decreased adaptivity in highly trained rowers appear to be decreased and increased resting levels of insulin and creatine kinase, respectively. The risk of the possible appearance of overtraining in studied rowers was further diagnosed by the higher exercise-induced increase in creatine kinase concentration after heavy training period. According to the results of this study, a heavy training period in studied rowers could be sustained for three weeks.

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CHILDREN'S AND ADOLESCENTS' PHYSICAL ACTIVITY IN RELATION WITH LIVING ENVIRONMENT, PARENTS' PHYSICAL ACTIVITY, AGE AND GENDER

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ABSTRACT

The purpose of this study was to examine how children's and adolescents' unorganised and organised sports activities were influenced by living environments and parents' physical activity The subjects were a random sample of 1873 boys and girls aged 9, 12, 15, and 18 years. These subjects completed questionnaires on physical activity, sport participation, living environments and parent's physical activity. Results showed that differences between living environments were larger in the organised sport than in the unorganised physical activity, larger in the boys than in the girls and larger in the team sports than in the individual sports. A 4 × 4 × 2 (Living Environments × Age × Gender) MANOVA on the unorganised and organised sports indicated that main effects for age and gender were significant for both sports activities. In urban environment sport participation was much more common than in rural areas. The age-related decline of the organised sport was steeper in boys than in girls, and that in the unorganised physical activity the decline by age was significant only in boys but not in girls. A $4 \times 3 \times 2$ (Living Environments × Fathers'/Mothers' Physical Activity × Gender) MANOVA on the organised sports showed that main effects for the environments, fathers' physical activity and were significant, accounting for 24%, 21% and 22% of the variance, respectively. Mothers' physical activity did not show a significant main effect for the organised sports, accounting for 9% of the variance. These results revealed that demographic factors affect the sports activities of children and adolescents, particularly in youth organised sport.

Key words: age, gender, children, adolescents, sport participation, physical activity, living environments, parental influence

INTRODUCTION

Physical activity has generally been recognised as having a positive effect on physical and mental health and functional capacity [1–6]. Both school physical education and youth sport are considered as a critical period to establish healthy behaviour patterns. Habitual physical activity provides children with the skills, values, preferences and expectations that are essential for adult sport socialisation and has a potential importance of maintaining an active lifestyle [7–10].

There is some research evidence of the importance of the organised sport in particular for young people and their later physical activity. Longitudinal studies have shown that participation in organised sport is a better predictor of physical activity in later life than unorganised physical activity [11–13]. It seems that organised sport is effective in teaching motor skills and developing intrinsic motivation. At school age organised sport correlates with fitness stronger than unorganised activity [14]. Concerning the development of skills, motivation and fitness the duration of sport training is important. Our studies have shown that although more than half of boys and about half of girls participate in sport training in clubs at some phase of their youth, the number of longer term participants is much smaller [13,15]. It may be that the internalisation of socialisation process focuses on connections between living environments, social, psychological and health factors that occurs not only in childhood and adolescence but also continuously throughout the adult age [16–21].

According to the well-known model of sport socialisation three elements are important in socialisation process: personal attributes, significant others and socialisation situations [22]. The availability of and access to the sport facilities are important factors regulating socialisation situations of youth. Therefore, the location of home in relation to sport facilities and living environment in general influence physical activity and sport participation.

It has been shown that there are marked regional differences in physical activity and sport of youths and adults in many countries [15,23–29]. In Finland, the difference between living environments has been found indicating that urban people have a higher occupational and social status, a higher educational level, more social and commercial intercourse, as well as they are more physically active in leisure time than that of rural people. Moving from one place to the other in general does not seem to influence the participation in physical activity, but moving from rural areas to urban areas increased the physical activity among boys [30,31]. Of the living environment variables the urban/rural dichotomy was clearly a better predictor of sport and physical activity than the geographical location of the home. Participation in sport clubs and team sports is more prevalent in urban children than in rural children. Also, urban children are more likely to persist in sports-club activities than their counterparts during a 3-year follow-up period [13,15].

There are differences between central urban and peripheral areas explaining different types of environments for socialization into certain physical activity. For example, people who live in rural environments may have greater opportunities to experience hunting, riding, fishing, boating and skiing, as well as other physical activities such as picking berries and mushrooms and swimming in lakes [32,33]. People who are reared in more urban areas may have higher probabilities of being exposed to park and sports facilities and learning skills associated with those activities [29]. It is obvious that if individuals are to become "familiar" with physical activities, they must live in places where they can learn the skills necessary to participate. In Finland, an important fact is that genuine rural environments still exist and the urban/rural difference influences young people's sports activities, particularly in organized sport. Urban children and adolescents have more choices of sports-club activities and more opportunities to utilize sport facilities and equipment than do rural counterparts. Young people living in small villages are separated by long distances, which makes it difficult to organize team sports for them. A similar situation has been found in Swedish youth sports [23]. Finally, rural children and adolescents are less likely to engage in sports activities during the slushy or dark period due to the relative lack of indoor sport facilities available to them.

The family, especially the parents' attitudes towards physical activity and their sporting behaviour, socio-economic status and living environments, constitutes a very important setting for the children' original interests of physical activity and sport. It has been found that the level of fathers' physical activity correlates with their children's physical activity [35–40]. Father's influence on children's physical activity is stronger than that of mothers [13,21,41]. The mothers' physical activity has been slightly controversial with respect to the children's physical activity. The physical activity of mothers is only related to girls' physical activity and to the unorganised physical activity, not so much to the sport participation [38,42,43]. Many studies have shown that father's influence is stronger that that of mother, but there seems to be cultural and age-related differences both in the influence of mother and father [19.41,44–49].

During past decades, the popularity of youth sport has increased which means that the share of organised sport in the total physical activity of young people has been growing in many countries [50]. The same phenomenon has been also seen in Finland but, however. in Finland a larger part of young people's physical activity is still non-organised than in many European countries [14]. Because organised sports take place in specially constructed sport facilities it can be expected that the urban environment is more favourable for organised sport than rural environment. Because the sport facilities may be located far away from home parents' support has become more important as organisers of transport. Therefore we would like to study parents' influence in different environments.

The age related decline of physical activity and sport participation has been well documented in many studies [20,50–51]. Age changes in sport and physical activity have shown that younger children are more likely to have a competition and performance orientation, and are more highly motivated by external factors such achievement/social status, encouragement by significant others and facilities, whereas older children are more likely to have recreation and relaxation motives, and are motivated by more internal factors such as fitness, skill improvement and excitement/challenge [53–58]. It can be expected that younger children are more dependent on the support from family and availability of possibilities for physical activity in close living environments than older adolescents.

There have been found gender differences both in motivation for physical activity and in the attitude of parents. Boys appear to have higher scores on competitiveness, win orientation and achievements, whereas girls appear to score slightly higher on fitness, friendship and having fun [59–65]. Boys value competence at sport more than competence at school, while girls value being good in school more than being a good athlete [66–71]. In comparison to boy and girl participants in competitive sport, non-competitive sport and non-sport achievement activities, girls are just as likely as boys to participate in non-competitive sport and to report non-sport achievement activities and interests [56]. In addition, boys experience a more rewarding and positively reinforced or supportive set of experiences that predispose them toward sport and physical activity. In contrast, girls do not receive systematic or consistent encouragement or tutoring in the development of motor skills [35,42,43,72]. Thus, gender role may influence the individual's emphasis on social comparison and winning within sport [62].

However, the gender differences in physical activity and sport participation have decreased in Finland and in other Nordic countries [15,50]. As measured with the frequency of physical activity the

Finnish girls older than fifteen are more active than the Finnish boys, but boys still are more active in organised sport than girls [20]. Telama et al. [15] suggest that female teachers offer a more efficient physical education curriculum programme to girls and develop their attitudes toward physical activity in Finnish schools. Also, Finnish sport associations create opportunities for both males and females to participate in various physical activities. The cognitions of both sexes change over time as a function of maturation and experience in physical activity and sport participation.

The purpose of the present study was to examine whether living environments and parents' physical activity are associated with the unorganised and organised sporting activities of children and adolescents, separately. Also of especially interest was whether the previously determined characteristics were age and gender interactions.

METHODS

Sample and procedures

The data were drawn from the Cardiovascular Risk in Young Finns Study which is an extensive multidisciplinary longitudinal project. The study was started 1980 when cohorts of randomly sampled 3-, 6-, 9-, 12-, 15- and 18-year-old boys and girls were examined first time. The measurements were replicated 1983, 1986, 1989 and 1992. The sample was taken from the five university towns with medical schools (Helsinki, Kuopio, Oulu, Tampere and Turku) and the surrounding communities. These five areas were chosen in order to take into account differences in living conditions and cardiovascular risks between southwestern and northeastern Finland. In each region the sampling was carried out using the national population register. The register covers the whole of the population in Finland and is kept continuously up-to-date. The sampling has been discussed in greater detail by Åkerblom *et al.* [73–75]. The subjects of the present study were 9-, 12-, 15- and 18-year-old boys and girls from the year 1986 with the same subjects (N = 1873) from the original data (N = 2243), the dropout rate being 16%. The Finnish population is rather homogeneous. The sample represents quite well the whole Finnish population of the same age. The results of other years have been used to show that there were no major changes between living environments during 9 years from 1980 to 1989. Due to financial reasons demographic variables of 1989 were investigated only from the city of Turku. The 1992 data are excluded from this study because there were different self-rated assessments of physical activity and no parental questions included. Nupponen & Telama [76], in the comparative study of physical activity and motor fitness in European youth, suggested that the social changes in Finland did not diminish the differences between urban and rural areas. Therefore, the data of 1986 was available in this study.

Measures

Physical activity and participation in sport were measured by means of a short self-report questionnaire which was administrated individually in connection with a medical examination [77]. Questions concerned the frequency and intensity of leisure-time physical activity, participation in sports-club training, participation in sport competitions, habitual way of spending leisure time, grades of physical education, way of commuting school, and type of sport participated in. In the questionnaire, subjects were also asked how many years they had been coached in order to measure long-term participation in intensive and organised sport.

Two kinds of indexes of physical activity were formed: unorganized physical activity index (UPA) and organized sporting activity index (OSA). The UPA, ranging from seven to twenty-three, was sum of the frequency and intensity of leisure-time physical activity, frequency of intensive physical activity, hours/week of intensive physical activity, grades of physical education, habitual way of spending leisure time, and commuting to school by bicycle or walking (Table 1). The OSA, ranging from five to sixteen, was formed summing the participation in sports-club and intensive training, participation in sport competitions, years of coaching training and types of sport (Table 2). The lowest scores indicate passive and the highest scores indicate active.

Table 1. The original scoring and re-coding of the items included in unorganised physical activity (UPA)

Items	Original score	Code for UPA
How often do you engage in leisure-time physical activity at least half an hour per time?		
Not at all	1	1
Less than once a month	2	1
Once a month	3	1
2–3 time a month	4	1
Once a week	5	2
2–6 time a week	6	2
Every day	7	3
How much are you breath-taking and sweating when you engage in physical activity and sport?		
Not at all	1	1
Moderately	2	2
Lot of	3	3
How often do you engage in intensive physical activity?		
Not at all	1	1
Once a month or more	2	1
Once a week	3	2
2–3 times a week	4	2
4–6 times a week	5	2
Every day	6	3
How many hours a week do you engage in intensive physical activity?		
Not at all	1	1
½ hour a week	2	1
1 hour a week	3	1
2–3 hours a week	4	2
4–6 hours a week	5	2
Over 7 hours a week	6	3
What do you usually do in your leisure time?		
I am usually indoors and read or do something like that	1	1
I spend my time indoors and outdoors, outdoors I usually walk or spend time with my friends	2	2
I am usually outdoors and exercise rather much	3	3

Items	Original score	Code for UPA
What grades of Physical Education do you obtain in the school's last spring diploma?		
Grades	4–7	1
Grade	8	2
Grade	9	3
Grade	10	4
How long and how do you usually go to school		
By car/bus	1	1
By cycling/other means within 400m	2	2
By cycling/other means within 700m or walking within 400m	3	3
By cycling/other means with over 800m or walking over 500m	4	4
Sum of UPA	Min. 7–	Max. 23

The coefficient of internal consistency (Cronbach's alpha) was calculated for all age-gender groups as an indicator of the reliability of the sum indexes. The coefficient varied from 0.51 to 0.77 in the unorganized physical activity, and from 0.71 to 0.90 in the organized sporting activity. The test-retest reliabilities of the index of physical activity estimated by the simplex-model were higher than 0.70 [78]. In the same research project, and in the same sample, a significant negative correlation was found between the index of physical activity and heart rate at rest, serum insulin, and skin fold measurements, which can be seen as an indication of the validity of the activity measure [79,80].

Fathers' and mothers' physical activity were measured by a simple question in the questionnaire administrated to parents: how much do they engage in physical activities? (1 = a little to 3 = regularly). Living environment was classified as four categories: urban centre, suburban, rural centre and rural area. For the calculation of correlations environment was dichotomised urban — rural.

Table 2. The original scoring and re-coding of the items included in organised sporting activity (OSA)

Items	Original score	Code for OSA
How many times a week do you usually engage in the training sessions of a sport club?		
Not at all	1	1
Occasionally	2	1
Less than once a month	3	1
Once a month or more	4	2
Once a week	5	2
Many hours and times a week	6	3
Do you participate in sports competition?		
Not at all	1	1
Sports-club level	2	2
Regional level	2	3
National level	2	4
Do you participate in intensive sports training under coaching?		
No	1	1
Yes	2	2
If you do, in which a sport event do you participate?		
No	0	1
Low intensive level (e.g., shooting, horse-back riding, etc.)	1	2
High intensive level (e.g., soccer, ice-hockey, swimming, etc.)	2	3
How many years do you participate in sports training under coaching?		
No	0	1
1 year	1	2
2 years	2	3
3 years up	3	4
Sum of OSA	Min. 5–	Max. 16

Statistical analysis

Means, standard deviations and intercorrelation (Pearson's) for all variables were computed in the present analysis. Multivariate analysis of variance (MANOVA) was performed to analyse the differences in living environments and parents' physical activity between unorganised and organised sports activities in the age-gender groups. Partial Eta squared (η_p^2) was computed between subgroups means whenever significant main effects were found by MANOVA. The associations of years of training under coaching and types of sport with living environments were tested by χ^2 test. The level of significance used was $p< 0.05$.

RESULTS

The means and standard deviations of unorganised physical activity index (UPA) and organised sporting activity index (OSA), by the independent variables, are given in Table 3. Table 4 indicated the intercorrelations of children's physical activity, living environment and parent's physical activity. There was a significant relationship between UPA and OSA. Living environments were significantly correlated with boys' UPA and OSA but not with girls'. Father's physical activity had a low but significant correlation with both indexes among boys and girls. The environments were also correlated with parents' physical activity of the boys, and with fathers' physical activity of the girls. Mother's physical activity correlated significantly only with the activity of boys but not with that of girls. However, the correlation coefficients were very low.

Table 3. Means and standard deviations of main variables for indexes of unorganised physical activity (UPA) and organised sporting activity (OSA)

Indexes Variables	N	UPA M	SD	*p*	N	OSA M	SD	*p*
Gender								
Boys	878	13.8	2.6		904	7.4	3.5	
Girls	934	13.2	2.6	.001	969	6.3	2.6	.001
Age								
9	468	13.7	2.1		487	6.4	2.5	
12	463	14.1	2.2		476	7.5	3.5	
15	485	13.3	2.7		491	7.1	3.4	
18	396	12.7	3.1	.001	419	6.1	2.7	.001
Living environments								
Urban centre	158	13.7	2.6		167	7.2	3.3	
Suburban	717	13.5	2.6		741	7.1	3,4	
Rural centre	450	13.6	2.5		459	6.9	3.1	
Rural area	456	13.3	2.5	n.s.	475	6.1	2.2	.001
Fathers' physical activity								
High	288	14.2	2.4		289	8.0	3.7	
Medium	632	13.7	2.3		657	6.8	3.0	
Low	298	13.1	2.5	.001	305	6.3	2.5	.001
Mothers' physical activity								
High	283	14.0	2.4		290	7.4	3.4	
Medium	735	13.7	2.3		758	7.1	3.2	
Low	359	13.4	2.5	.01	365	6.6	3.0	.01

Note: n.s. = non significant.

Table 4. Correlations between two sport-activity indexes, living environment and parents' physical activity among boys and girls (ages 9, 12, and 15 years)

Variables	1	2	3	4	5
1 UPA	–	40**	–.03	.14**	.07
2 OSA	.44**	–	.07	.19**	.06
3 Living environment	.09*	.17**	–	.15**	.06
4 Fathers' physical activity	.17**	.18**	.20**	–	.24**
5 Mothers' physical activity	.10**	.10**	.08*	.40**	–

Note: The figures for boys in the lower diagonal (left), for girls in the upper diagonal (right).
* p<.05, ** p<.01

A multivariate 4 × 4 × 2 analysis of variance (MANOVA) for living environments (urban centre, suburban, rural centre and rural area), age (9, 12, 15 and 18 years) and gender on the UPA indicated that no three-way interaction effects were significant. The environment × gender interaction was significant ($F_{(3,\ 1749)} = 3.06$, $p < 0.05$), accounting for 11% of the variance. Also, the age × gender interaction was significant ($F_{(3.\ 1749)} = 3.87$, $p < 0.01$), accounting for 13% of the variance. The environment × age interaction was not significant but the age differences seem to be different in different environments. Age and gender contributed significant main effect to children's unorganised sport, accounting for 21% and 11% of the variance, respectively. The environments did not show a significant main effect for the UPA, accounting for 9% of the variance. This result also means that boys are more active than girls only in 9- and 12-year-olds, but not in older groups. In general the gender difference is small in the UPA. The UPA values among urban centre boys do decline by age and among urban centre girls the value increases (Figure 1).

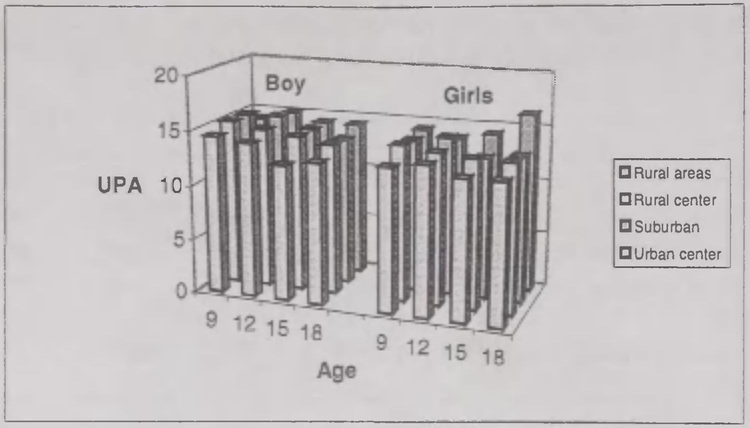

Figure 1. Unorganised physical activity (UPA) by living environment, age and gender

The same 4 × 4 × 2 MANOVA for the OSA showed that no three-way interaction effects were significant. The interaction between the environments and gender was significant ($F_{(3,\ 1810)} = 4.41$, $p < 0.01$), accounting for 13% of the variance. Also, the interaction between age and gender was significant ($F_{(3,\ 1810)} = 3.82$, $p < 0.01$), accounting for 12% of the variance. However, the interaction between the environments and age was not significant, accounting for 9% of the variance. The environments, age and gender contributed significant main effect to children's organised sport, accounting for 22%, 26% and 20% of the variance, respectively. The relationship between age and the OSA is not linear. In both genders the age of 12 is the most active age to participate in organised sport and this is most evident in urban centres (Figure 2).

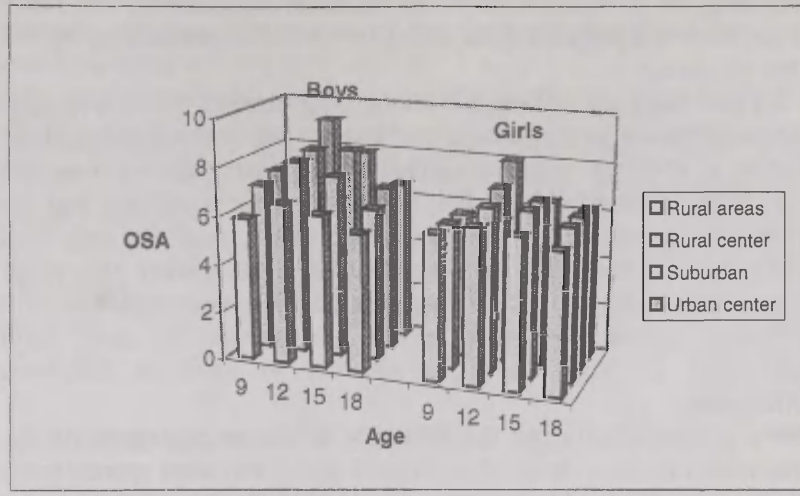

Figure 2. Organised sporting activity (OSA) by living environment, age and gender

4 × 3 × 2 MANOVA for living environments, fathers' physical activity (FPA: low, moderate, high), and gender on the OSA indicated that no three-way interaction effects were significant. The environments × gender interaction was significant ($F_{(3,\ 1206)} = 3.73$, $p < 0.05$), accounting for 15% of the variance. Both the environments × FPA and FPA × gender interactions were not significant. The environments, fathers' physical activity and gender contributed significant main effect to children's organised sport, accounting for 24%, 21% and 22% of the variance, respectively.

The same kind of the 4 × 3 × 2 MANOVA for the environments, mothers' physical activity (MPA: low, moderate, high) and gender on the OSA showed that there were no significant three-way interaction effects. The interaction between the environments and gender was significant ($F_{(3,\ 1364)} = 2.99$, $p < 0.05$), accounting for 13% of the variance. Both the environments × MPA and MPA × gender interactions were not significant. The environments and gender contributed significant main effect to children's organised sport, accounting for 23% and 25% of the variance, respectively. The MPA did not show a significant main effect for the OSA, accounting for 9% of the variance.

In order to see the influence of living environments on the long-term sport participation a cross-tabulation between the environments and the duration of sport training was carried out separately among boys and girls (Table 5). Among boys the relationship was significant and the differences between the environments were great in long-term participation (3 years and up) in particular, participation percentage being in urban centre 22 but in rural area only 4. Among girls the main differences between different environments were in short term participation (2 years and less) and not so much in long-term participation.

We also wanted to see the influence of the environments on the participation in the training of individual sports and team sports. Table 5 showed that in both genders the main differences between the environments were in team sport training. No girls in rural area participated in team sport training. 7.5% of boys in rural area participated when the respective percentage in urban centre is 29.7.

Because our main data are from the year 1986 it is relevant to check the possible changes by time. The age group of 12-year-olds was the one of which we had a sample from every four measurements. In Figure 3 it can be seen that during 9 years from 1980 to 1989 there were no remarkable changes in the differences between the environments. Similar results were found in the age group of 15-year-olds.

Table 5. Distribution (%) of participation in years of training under coaching and types of sport among boys and girls (combined ages 9, 12 and15) in different living environments

Living environments Sports	Boys				Girls			
	Urban centre	Sub-urban	Rural centre	Rural area	Urban centre	Sub-urban	Rural centre	Rural area
Years of training								
Non-participants	60.9	62.3	72.5	88.7	79.3	82.1	88.3	93.3
≤ 2 years	17.2	18.9	14.3	7.0	15.5	.3	6.9	3.6
≥ 3 years	21.9	18.8	13.2	4.3	5.2	8.6	4.8	3.1
N	64	276	189	186	58	281	189	194
Sign. (X^2)		$p<.001$					$p< .01$	
Type of sport								
Non-participants	59.4	62.3	70.4	88.7	79.3	81.1	87.8	92.3
Individual sports	10.9	12.3	10.0	3.8	6.9	12.5	6.9	7.7
Team sports	29.7	25.4	19.6	7.5	13.8	6.4	5.3	0.0
N	64	276	189	186	58	281	189	194
Sign. (X^2)		$p<.001$					$p<.001$	

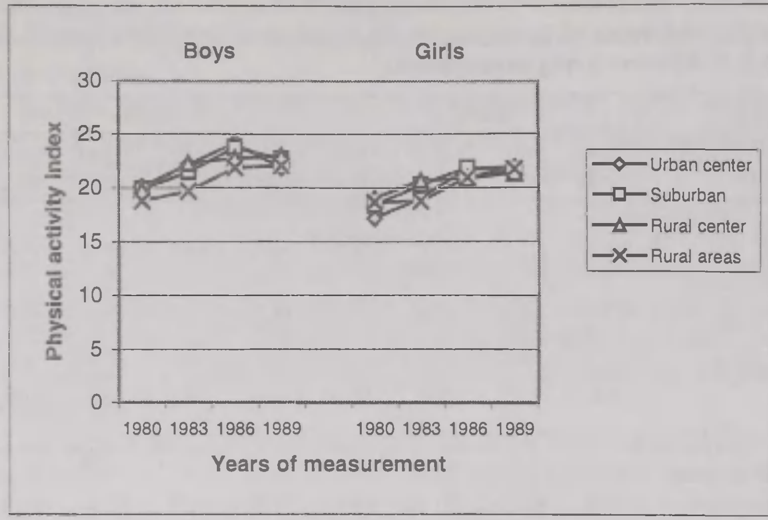

Figure 3. The level of physical activity by living environment in four measurement years among 12-year-old children

DISCUSSION

The present results showed that the living environment, more specifically the degree of urbanisation, was an important factor regulating physical activity and particularly sport participation of young people. The more urbanised living environment the more frequent is the sport participation. The participation is least in sparsely populated rural areas. The finding, which we would like to point out, was that the environment influenced strongly in particular on organised sport. Although the physical activity of young people have become more organised during the last decades in many European countries including Finland [47,50,81], the results concern Finland which differs from most Western industrialised countries. It is a reasonable fact that in Finland the population density is low and still a part of the population is living in sparsely populated rural areas. Also, it can be supposed that the long distances to the sport facilities and training sessions may be problems in the countries where population density is higher.

The significant environment × gender interaction was an interesting finding. The environment influenced only boys' sports activities, not that of girls. A surprising result was that not even the participation in organised sport among girls was influenced by environment. The environment only influenced girls' team-sport participation but sport participation in general. The reason probably is that girls participate in different sport disciplines than boys. The main sport events in organised sport of boys are mainly team sports, such as soccer, ice-hockey, basketball and indoor bandy while the main organised sports for girls are track and field, skiing, horse-back riding, swimming and basketball [14]. In sparsely populated areas it is more difficult to organise training in team sports than in individual sports. This was confirmed by the results of cross-tabulation showing that the differences between environments were bigger in team sports than in individual sports. The finding that the unorganised physical activity was influenced by environment among boys but not among girls is probably also explained by the differences in recreational physical activities. Although some individual activities like cycling and jogging are high on the list of most popular recreational physical activities of boys, the team sports like soccer, ice hockey and indoor bandy have an important role also in the unorganised recreational physical activities of boys, while the girls' most popular recreational activities are individual only (e.g., jogging, cycling, walking, swimming) [14].

The results of this study confirmed only partly the findings of previous studies concerning age and gender differences in physical activity. Boys are more active in organised sports in particular but also in unorganised physical activities. However, in unorganised physical activity the gender difference was small and it only concerned 9- and 12-year-olds but not 15- and 18-year-olds. At age of 18 girls were even a little more active than boys. Thus, the results supported the previous findings according to which in Finland and in some other Nordic countries the gender difference in physical activity is smaller than in most other countries [14,47,50]. One explanation can be rather high physical activity of Finnish woman as related to the women in many other countries. According to the frequency of physical activity young Finnish women are physically more active than young men [15,20]. In organised sports girls in average were more active but in rural environment there no clear difference in sport participation between boys and girls. The main reason for this may be that the means of both genders are almost at the minimum level, i.e. the organised sport is almost lacking in rural areas.

Also the age-related decline of physical activity was re-evaluated in this study concerning the type of physical activity and gender. In unorganised physical activity of girls the main effect of age was non significant. The decline by age in organised sport of girls was not so steep as that among boys. The participation in organised sport increased from the age of 9 to 12 after which the decline starts. The decline after the age of 12 was steepest among boys living in urban centres and very steep also among urban girls from the age of 12 to 15. The urban centres can offer the best opportunities for organised sport and encourage to join into sport training. However, it seems that the availability of facilities and coaching does not guarantee the continuous participation and the decline starts.

The findings also supported the previous studies on the relationship between fathers' physical activity and children's sports activities [34,39,44.48]. It can be suggested that the influence of fathers is strongest among the children living in urban areas and the weakest in rural areas. This is quite expected. What fathers can do is to take children to the sport club, organise continuous transportation, and to motivate and encourage children to continue participation. This is easy to do in urban environments where the facilities and training are available. In rural environments fathers cannot help so much if the facilities are lacking. However, the differences between mothers' physical activity and children's sports activities disappeared after adjustment for living environments and gender. This is in agreement with the results of some previous studies [38,43] suggesting that the physical activity of mothers is merely related to the children's sports activities.

Referring to the model of the socialization process [22], this study emphasises the role of significant others, in this case parents, and especially the socialising situations represented here by living environments. The results indicated that sports activities were most prevalent among boys and girls whose fathers had a high level of physical activity in urban environment. The role model provided by sporting parents not only improves children's cognitive appraisal, which may help them to cope with stressful sports, but also provides them with emotions and norms for appropriate behaviour in life. The living environment may contribute to explaining demographic and socio-economic differences in physical activity. The most important is that urbanisation has a formative effect on individuals' physical activity [15]. The development according to which the physical activity of young people is changing from spontaneous unorganised activity to organised sport may mean that the sports activities of young people become more and more dependent on the living environment which increases the inequality in their physical activity and sport participation.

In conclusion, the results from this study show that urban boys and girls are more likely to participate in organised sports than rural counterparts, particularly for the age group of 12 years. Boys are more physically active than girls at the age of 9, 12 and 15 years. The level of sports activities is declined with age, particularly among boys. Sports activities were most evident among boys and girls whose fathers had a high level of physical activity in the urban environment, but not found in whose active mothers. The society is really changing all the time and the urbanisation process is still going on which means that less and less people are living in real rural environment. However, the urbanisation process does not necessarily diminish the differences between urban and rural environments in Finland. On the other hand still lot of people are living in rural areas [76]. Since the differences between urban and rural environments are still exited, further research is required to analyse the motives for sports activities among children and adolescents living in different environments.

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EFFECT OF FAT AND L-CARNITINE INGESTION ON BICYCLING PERFORMANCE

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ABSTRACT

The aim of this study was to examine how ingestion of mediumchain triacylglycerols (MCT) and L-carnitine may affect the metabolism during long lasting submaximal exercise. We also looked at the performance in a subsequent supramaximal sprint to exhaustion. On two different days nine well-trained cyclists aged 26±8 yr (mean±SD) cycled for 2 h at a power giving a blood lactate concentration of 2 $mmol \cdot l^{-1}$ (the aerobic threshold). On each day they ingested either a carbohydrate drink or a drink containing altogether ~24 g of MCT and 2 g of L-carnitine in addition to carbohydrates. After each 2 h ride the subjects carried out a high intensity ride (~700 $J \cdot kg^{-1}$) as fast as possible (~160 s). Ingestion of MCT and L-carnitine had no effect on the O_2 uptake, respiratory exchange ratio, heart rate, or Borg's rating of perceived exertion during the 2 h ride. The duration and the accumulated O_2 deficit of the supramaximal sprint were not affected by fat intake. For both experiments the sprint performance was reduced compared with the results on a control day with a sprint without 2 h previous bicycling. The MCT drink showed no adverse effects and may be used as an alternative to drinks that contain only carbohydrates.

Key words: Glycogen sparing, O_2 uptake, ratings of perceived exertion, aerobic threshold, exercise

INTRODUCTION

Even with an optimal loading and supply of carbohydrates before and supplementation during exercise, the stores may eventually run short during exercise lasting more than 1 h. Athletes will in that situation have difficulties with performing high-intensity exercise that requires glycolytic energy liberation, for example the finishing sprint of a bicycle race. It has therefore been proposed that increased fat intake may spare muscle glycogen and thus enhance the performance during prolonged exercise [6, 7]. Medium-chain triacylglycerols (MCT) contain fatty acids of 6–12 carbon atoms. Contrary to triacylglycerols with longer fatty acids the medium-chain triacylglycerols are easily digested and absorbed, especially when co-ingested with carbohydrates [10]. Thus, medium-chain fatty acids might be a suitable substrate for fatty acid oxidation and thereby spare glycogen during long lasting exercise.

The effect of MCT ingestion on the metabolism and/or endurance time has been investigated in several studies [3, 5, 8, 9, 10, 11, 12, 15, 25, 26]. But only one [26] found a positive effect on performance after MCT ingestion. When looking for sport performance enhancements, the performance test should be as specific to the sport as possible. While former studies have used exercise durations of 15–70 min as performance criterion [19, 26], sprints seldom lasts more than 2 min in a traditional road cycling race. We therefore used a finishing sprint that would last ~2 min as our performance test; that duration is the minimum to allow a maximum anaerobic energy release [18, 19, 20].

Long-chain triacylglycerols (LCT) need L-carnitine to enter the mitochondria, and it has been speculated that ingestion of L-carnitine may facilitate the oxidation of LCT [2]. This study was carried out to see if *the combined* ingestion of an easily tolerable amount (24 g) of medium-chain triacylglycerols together with 2 g of L-carnitine and ~120 g of carbohydrates during 2 h of bicycling can increase the oxidation of fat in highly trained individuals and thus perhaps spare muscle glycogen. If so, the performance in a subsequent all-out sprint of 2–3 min duration would probably be better, and in addition the anaerobic energy release would presumably be larger.

MATERIAL AND METHODS

Subjects

Nine subjects, six of them belonging to the Norwegian elite in Mountain Bike Cycling (Junior and Under 23) and three special long distance cyclists (age span 33–40), volunteered to serve as subjects. Before giving their written consent each subject was informed about the experiment, the purpose, and the procedures involved. It was particularly stated that voluntary participation meant that they were free to leave the study at any stage without giving a reason for doing so.
The subjects had an age of 26±8 yr (average±SD) with a range of 18–40. Their body mass was 74±8 kg (range 55–83), height 1.78±0.06 m (range 1.66–1.87). The $VO_{2\text{-peak}}$ was 46±5 $\mu mol \cdot kg^{-1} \cdot s^{-1}$ (range 38–52; 62±7 $ml \cdot kg^{-1} \cdot min^{-1}$).

Procedures

Step protocol
Each subject reported to the laboratory four times. During Day 1 a step protocol was used to establish a power that elicits a blood lactate concentration of 2 mmol l^{-1}. For our subjects that power corresponds to ~60% of the maximal O_2 uptake or ~70% of the maximal heart rate and is here called “the aerobic threshold” [4].

Endurance cycling
On two separate days (Days 2 and 3) the subjects cycled for 2 h at the power established during the first day. The two days were separated by at least 48 h. During each ride each subject was given approximately 2 L (25–30 $ml \cdot kg^{-1}$ body mass) of a drink containing either 60 $g \cdot l^{-1}$

carbohydrates only (CHO-drink) or a drink containing 60 $g \cdot l^{-1}$ carbohydrates, 12 $g \cdot l^{-1}$ medium-chain triacylglycerols and 2 g L-carnitine (MCT drink). The MCT emolution (Triglycerida Saturata Media Lamotte, Bremen, Germany), consists of 75% C-8 (carpylic acid) 20%, C-10 (capric acid) and 5% LCT, oleic acid (C-18:1). Just before start they drank about 300 ml, and they then continued to drink between 250 and 300 ml each 15 min until 1 h 40 min of bicycling. The order of the two drinks used for day 2 and day 3 was randomised. After 10 min of exercise on day 2 the blood lactate concentration was measured for intensity control. For four of the subjects a value higher than 2.5 $mmol \cdot l^{-1}$ was found, and the power was therefore reduced by 10–30 W after 20 min of exercise. For one subject the power was raised by 15 W. On Day 3 each subject started out at the same power as on Day 2, and for the same subjects the power was adjusted after 20 min of bicycling as on the previous day. Five of the subjects exercised on an electrically braked ergometer (LifeCycle, LifeFitness/Brunswick Corporation, Franklin Park, Illinois, USA), one on a mechanically braked Monark 824E (Monark Exercise, Varberg, Sweden) and three on an electromechanically braked Krogh-type bicycle ergometer [13]. The experiments were carried out at room temperature, 20–22°C. A 60 W fan blew air to the subjects' upper body during exercise, thus easing convective and evaporative heat loss.

After 15, 45, 75, and 105 min of exercise the O_2 uptake was measured by collecting expired air in three Douglas bags over a period of 5 min. The heart rate and the subjects' rating of perceived exertion were also recorded four times at 30 min intervals. A capillary blood sample for lactate measurement was taken after each 2 h ride.

Sprint cycling

Within 10 min after the 2-h ride the subjects carried out a simulated 1000 m sprint bicycling as fast as possible on a bicycle ergometer. This was done by carrying out a pre-set work of 638 $J \cdot kg^{-1}$ body mass on the Krogh ergometer; for the Monark ergometer this corresponds to a load of 65 $g \cdot kg^{-1}$ body mass for a distance of 1000 m at the bicycle's display. The subjects were instructed to cover the distance in the shortest possible time. Throughout the sprint they received verbal encouragement. During the second and third sprints the subjects were guided according to their first run for the first quarter of the sprint to avoid changes in tactics. Expired air was continuously collected in four Douglas bags throughout the sprint for later analysis of the O_2 uptake, each bag covering "250 m" or 160 J·kg^{-1} body mass of bicycling. Capillary blood samples were taken for lactate measurements 1 min and 3–4 min after the sprints.

After all the experiments were completed it appeared that there was an error in the distance counter of the Monark ergometer, so the six subjects using this ergometer actually covered a distance of around 1400 m at the pre-set load, corresponding to a work of around 900 J·kg^{-1} body mass. This has caused a large variation in the individual sprint times since the remaining three subjects did their 638 J·kg^{-1} work on the Krogh-type bicycle ergometer. However, since each subject used the same ergometer for all his tests and comparisons are done between different experimental conditions (CHO-feeding, MCT-feeding, or the control experiments described below) and not between subjects, that technical error should have no influence on the results or conclusions drawn in this study.

Lactate profile and final sprint

During the last day (Day 4) a full lactate profile test was carried out. Each subject cycled for 5 min at a constant power before the power was increased stepwise and a new 5 min exercise was carried out. This was repeated 8–12 times at powers ranging from 1 to 5.6 W·kg^{-1} body mass. The O_2 uptake was measured during the last minute of each power, and a 25μl blood sample for lactate measurement was taken immediately after each step and before the power was increased. After a 30–40 min rest and a new warm-up a final "1 000 m" or 638 J·kg^{-1} sprint was carried out as a control experiment of the performance without a preceding 2 h ride to see what effect the 2 h ride at the aerobic threshold had on the sprint performance.

The regression line from the measurements of the O_2 uptake versus power was used to calculate the accumulated O_2 deficit [18]. The regression parameters were: Y-intercept, 4.0±2.1 μmol·kg^{-1}·s^{-1} (mean±SD; 5.3 ml·kg^{-1}·min^{-1}); slope, 8.7±0.7 mmol·J^{-1} (195 ml·J^{-1}); error of regression, 0.7±0.3 μmol·kg^{-1}·s^{-1} (1.0 ml·kg^{-1}·min^{-1}); error of the slope, 0.3±0.2 mmol·J^{-1} (3%, 6 ml·J^{-1}); correlation coefficient, 0.996±0.003.

Measurements and equipment

The heart rate (HR) was recorded with monitors from Polar Electro (Polar OY, Kempele, Finland). Ratings of perceived exertion (PRE) were registered on the 15 point Borg scale [2] running from 6 to 20. Fractions of CO_2 and O_2 and the expired volume were measured on electronic analysers (O_2: S-A/I; CO_2: CD-3A; expired volume: S430A; sensors from Applied Electrochemistry, Pittsburgh, PA, USA). The O_2 uptake was also measured with a Metamax CBS (Cortex Biophysik GmbH, Leipzig, Germany). Data on the O_2 uptake from two experiments were lost because of leaky tubes leading expired gas to the S3-A O_2-sensor. The data from the Metamax were then used after reducing the measured values by 2%, a correction factor that was obtained from the parallel measurements done (not shown).

The blood lactate concentration was measured on an YSI 1500 (Yellow Spring Instruments, Yellow Springs, Ohio, USA) using haemolysed capillary blood taken from washed and prewarmed fingertips. Separate control studies showed that this instrument reported blood lactate concentrations 13% too high [16]. That systematic error is of little importance in this study.

The accumulated O_2 deficit during each simulated 1000 m exercise was determined according to the principles of Medbø et al. [18] and used as a measure of the anaerobic energy release during each sprint. The O_2 demand was taken from the relationships between the O_2 uptake and power established on Day 4. The accumulated O_2 demand is per definition the O_2 demand integrated by the exercise duration. Medbø et al. described these calculations for treadmill running [18] or bicycling [19] at constant speed or power. The constant O_2 demand was estimated from its linear relationship to the treadmill speed or power, and the integration is in that case reduced to the product of the O_2 demand and the exercise duration, that is to a simple multiplication. Our subjects cycled at a varying power, and therefore the simplified approach by Medbø et al. [18] cannot be used here. Instead the accumulated O_2 demand was taken as the integral of the O_2 demand by the exercise duration, T. First the O_2 demand was taken as

$$O_2\ demand = \mathrm{a} + \mathrm{b}\ P$$

where a and b are the intercept and the slope, respectively, of the individual relationships between the O_2 demand and the power. The recorded work W done is per definition $W = {}_0\int^T P\,dt$. Thus the accumulated O_2 demand was taken directly as

$$Accum.\ O_2\ demand = {}_0\int^T (O_2\ demand)\,dt$$
$$= {}_0\int^T (a + b\,P)\,dt = aT + b\,{}_0\int^T P\,dt = aT + bW$$

where the four entities a, b, T, W where known from the pre-tests (a, b; day 4) or recorded during the particular experiment in question (T, W).

Statistics and calculations

For four subjects the power was reduced after 20 min of bicycling during the 2 h rides. This would affect the measured O_2 uptakes and heart rates, and it could in principle mask a possible drift in the O_2 uptake during the rides. However, linear relationships of the O_2 uptake and heart rate versus the power were established for each subject during day 4. These relationships were used to calculate how the changed powers might have affected the measured values.

The carbohydrate oxidation was calculated from the measured O_2 uptakes and respiratory exchange ratio (RER), assuming that an RER of 0.70 represents pure fat oxidation and a value of 1.00 reflects pure carbohydrate oxidation, and that the relative oxidation of carbohydrate increases linearly by the RER-value between these two extremes. For calculations of glycogen used the active muscle mass was set to 23% of body mass [21], and possible changes in the liver carbohydrate stores were disregarded.

The results are given as mean±SEM. Differences between trials were analysed with paired *t*-test and Wilcoxon test (Windows Kwikstat professional 4.5, TexaSoft, Cedar Hill, Texas, USA) using Bonferroni correction for repeated comparisons. Scores obtained on an ordinal scale (perceived exertion) were also tested using the sign test, and these tests confirmed the other tests. Possible drifts in the O_2 uptake and the respiratory exchange ratios were examined by regression analysis.

RESULTS

The subjects exercised twice for 2 h at a power of 212±13 W (2.87±0.13 $W \cdot kg^{-1}$ body mass). The heart rate averaged 153±5 bpm for both trials. The O_2 uptake was stable at 30±2 $\mu mol \cdot kg^{-1} \cdot s^{-1}$ (40±2 $ml \cdot kg^{-1} \cdot min^{-1}$) throughout the exercise, thus showing no drift by time (Figure 1a). Admittedly, we reduced the load for some of the subjects, but that reduction would result in no more than a barely detectable decrease of 1.1 $\mu mol \cdot kg^{-1} \cdot s^{-1}$ in the O_2 uptake, and that effect is too small to mask a possible drift in the measured O_2 uptake. The respiratory exchange ratio averaged 0.88±0.01 for both experiments, but the value fell somewhat throughout both exercises ($P<0.001$; Figure 1b). Neither the O_2 uptake nor the respiratory exchange ratio differed between the two feeding types.

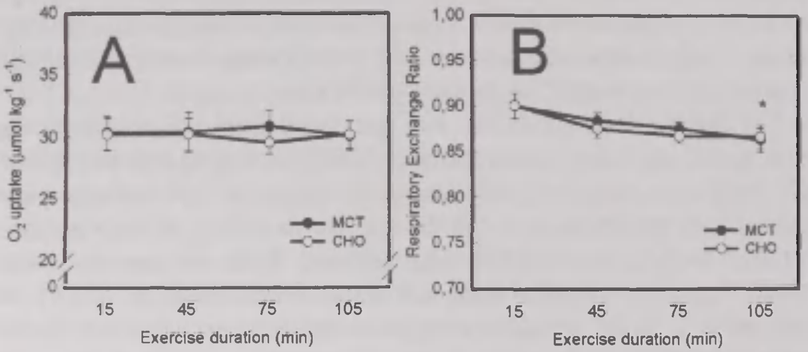

Figure 1. O_2 uptake (A) and Respiratory Exchange ratio (B) during 2 h bicycling at a 2 $mmol \cdot l^{-1}$ blood lactate concentration. The subjects were fed either a carbohydrate drink (CHO) or a drink containing carbohydrates plus medium-chain triacylglycerols (MCT). The data are mean±SEM of nine subjects. For four of the subjects the load was reduced after 20 min cycling. This represents a reduction in the O_2 uptake of ~1 $ml \cdot kg^{-1} \cdot s^{-1}$.* denotes a significant change from 15 min to 105 min ($P<0.05$).

The subjects rated their perceived exertion between 11 and 14 on the Borg scale, corresponding to "light" and between "somewhat hard" and "hard". There was no difference between the two trials. In all but three of the experiments the subjects reported an increasing exertion during the experiments, and consequently the value rose by 2±1 points during each trial (P<0.01; Figure 2).

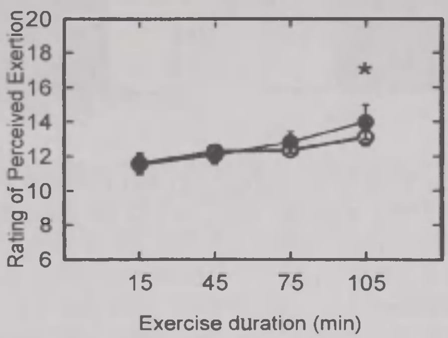

Figure 2. Ratings of perceived exertion during 2 h bicycling at the aerobic threshold. The subjects were fed either a carbohydrate drink (CHO) or a drink containing carbohydrates plus medium-chain triacylglycerols (MCT). The data are mean±SEM of nine subjects. * denotes an increase during the exercise (P<0.05).

The blood lactate concentration after 2 h bicycling was 1.9± 0.4 $mmol \cdot l^{-1}$ for the MCT-trial and 2.0±0.3 $mmol \cdot l^{-1}$ for the CHO-trial, confirming that the exercise had been carried out at the specified power.

After the 2 h rides and during the control experiment each subject carried out a "1000 m" sprint as fast as possible. The accumulated O_2 deficit of 1.3±0.2 $mmol \cdot kg^{-1}$ (30±4 $ml \cdot kg^{-1}$) body mass did not differ between the two rides carried out after 2 h bicycling, but the values were 32% less than that of the control experiment of 2.0±0.2 $mmol \cdot kg^{-1}$ (44±4 $ml \cdot kg^{-1}$; P<0.008; Figure 3a). The sprint duration did not differ between the two feeding types, but it was 15 s shorter in the control experiment (P<0.04; Figure 3b).

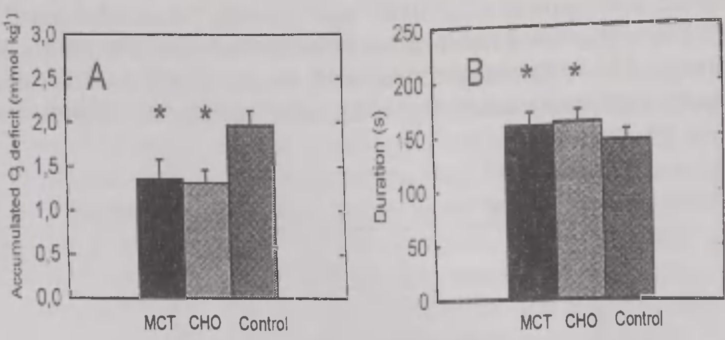

Figure 3. The accumulated O_2 deficit (A) and duration (B) of a constant work of 638 $J{\cdot}kg^{-1}$ body mass or "1000 m" on the Monark ergometer at a load of 65 $g{\cdot}kg^{-1}$ body mass carried out after 2 h of bicycling at the aerobic threshold (CHO and MCT-trials) or without preceding exercise (control). During the 2 h bicycling the subjects were fed either a carbohydrate drink (CHO) or a drink containing carbohydrates plus medium-chain tria-cylglycerols (MCT). The data are mean±SEM of nine subjects. * denotes a value different from that of the control experiment ($P<0.05$).

The peak post-exercise blood lactate concentration for all three trials after the sprint exercise was 13.7±5.2 $mmol{\cdot}l^{-1}$, indicating that despite the prolonged bicycling, glycogen stores were sufficient for a conside-rable lactate production. There was no difference between the two feeding types or the control experiment.

The total carbohydrate oxidation was 250±20 g for the CHO-trial and 256±18 g when ingesting MCT, as calculated from the measured O_2 uptakes and respiratory exchange ratios. The mean CHO-intake was 116±4 g, so the body stores were reduced by ~135 g carbohydrates. This represents a carbohydrate depletion of 44 $mmol{\cdot}kg^{-1}$ wet muscle mass (disregarding possible hepatic storage or supply), which is 40–50% of the normal resting values.

DISCUSSION

Ingestion of medium-chain triacylglycerols (MCT) and LCT with L-carnitine plus carbohydrates had no additional effect compared with that of pure carbohydrate feeding neither on the metabolism during 2 h bicycling nor on the performance of a subsequent sprint after the ride. For both feedings the performance of the sprint was reduced compared with that of a control experiment without preceding exercise.

Metabolism during the 2 h ride

Our well-trained subjects exercised for 2 h at around 60% of the maximal O_2 uptake. At that intensity well-trained subjects would expectedly oxidise both fats and carbohydrates, and our data on the respiratory exchange ratio suggest that carbohydrates covered around 60% of the energy release during both experiments. Our hypothesis was that ingestion of MCT and L-carnitine during exercise would increase the fat oxidation at the power used, but that hypothesis is not supported by our data since the subjects appeared to oxidise as much carbohydrates when fed fat as when they received only carbohydrates.

Fat oxidation usually becomes more important as the exercise is continued [6]. In line with this we saw a slight drop in the respiratory exchange ratio during the 2 h rides. That fall was independent on the type of feeding used. Thus, our data suggest that ingesting MCT and L-carnitine together with carbohydrates during the 2 h ride had no effect on the substrates used for oxidation at any stage during the ride and so probably did not spare muscle glycogen. Plasma FFA may be less important as a fuel source for trained subjects than for untrained ones [14], but Bergman et al.[1] could not find any effect of training on the reliance on the intramuscular triacylglycerol stores. Romijn et al. [24] found that at an exercise intensity of 65% of the maximal O_2 uptake the muscles of trained subjects make more use of their intramuscular triacylglycerols than at exercise intensities of 25% or 85% of the maximal O2 uptake. Therefore, if the muscles of endurance-trained subjects are able to supply the major portion of the fatty acids oxidised by use of their intramuscular triacylglycerol stores, this may be one reason for the lack of effect of the substrate ingestion used in our study. Our data on the respiratory exchange ratio and O_2 uptake suggest that the subjects oxidised around 70 g (~250 mmol of fatty acids or 3.8 g of fat kg^{-1} muscle) of fat during the 2 h bicycling, an amount that can be delivered by the intramuscular fat depots of the active muscle mass. Romijn et al. [24] found that during exercise at moderate intensity the fraction of the contribution from intramuscular substrates to the total energy expenditure declined after about 90 min of exercise. Thus, if the exercise duration had been more than 2 h, plasma-born fatty acids might perhaps have become more important.

Performance and the performance test

It took the subjects as long time to complete the ~1000 m sprint test when fed MCT, L-carnitine plus carbohydrates as when fed only carbohydrates during the 2 h bicycling, and it took 15 s longer to complete these sprints than in the control situation without 2 h preceding bicycling. The sprints lasted 2–3 min, a duration sufficient to tax the anaerobic energy release maximally [18, 19, 20]. The accumulated O_2 deficit was similar for the two feeding experiments and only 68% of the value of the control experiment. Thus, 2 h bicycling reduced the subjects' ability to carry out high-intensity exercise irrespective of the feeding used, presumably because of a reduced ability to release energy anaerobically. For the control experiments our values on the accumulated O_2 deficit do not differ much from the values of other experiments [19, 22]. Thus, this study is to our knowledge the first to show that 2 h bicycling at a moderate intensity leads to a reduced anaerobic energy release during a subsequent bicycle "sprint".

Our data suggest that the subjects' muscle glycogen stores fell by about 44 mmol kg^{-1} wet muscle mass (probably 40–50% of the preexercise stores) during the 2 h exercises, independently of the type of feeding. The subjects' rating of perceived exertion also suggests that they were not close to exhaustion after 2 h of bicycling. Even with a depletion that large the blood lactate concentrations after the sprints as well as the accumulated O_2 deficits suggest that there was a considerable lactate production in all experiments. In the normal situation lactate production accounts for ~75% of the anaerobic energy release during a 2–3 min ride to exhaustion [20]. Thus, if the reduction in the anaerobic energy release seen after 2 h bicycling was caused by a reduction in the lactate production only, lactate production was still more important than phosphocreatine breakdown in terms of energy release.

The high and similar blood lactate concentrations after the three sprints should be interpreted with some caution. The peak blood lactate concentration differs systematically between subjects and test conditions [17], probably because the distribution volume of lactate released to the blood may vary between different situations [21]. Thus, the high blood lactate concentrations seen after sprints carried out after 2 h of bicycling could mean that in that situation lactate released from the muscles is distributed in a smaller volume.

Our subjects cycled for 2 h at room temperature, and they sweated a lot. However, since the subjects ingested around 2 l of fluid, dehydration should be no problem. In fact, several subjects needed to empty their bladder during the 10 min break between the 2 h ride and the following sprint-test.

While we saw no effect of ingested medium-chain triacylglycerols on the performance, van Zyl et al. [26] found a better performance in a ~70 min long time trial. Before that test their subjects rode for 2 h at 60% of the peak VO_2, and during that ride they ingested 2 l of a drink containing 10% of carbohydrates (CHO) and 4.3% of medium-chain triacylglycerols (our drinks contained 6% CHO and 1.2% MCT). Goedecke et al. [5] used the same time trial as van Zyl et al. [26] but a somewhat lower dose of MCT. Jeukendrup et al. [12] used a similar protocol and with an equal MCT-load as van Zyl et al. used, but Jeukendrup used a 15 min time trial. None of these latter studies found any positive effect on the performance after ingesting MCT together with carbohydrates. When MCT was ingested without any carbohydrates, the performance fell [12, 26]. Thus, it may be that the beneficial effect of MCT-ingestion seen by van Zyl et al. [26] can be a combined effect of the maximal effort and long duration of their performance test and the large dose of MCT ingested.

Several other studies have used similar 1–2 h of exercise at ~60% of the maximal O_2 uptake and feeding either before [3, 8, 15, 25] or during the exercise [10, 11, 12]. None of the studies found a better performance after ingesting medium-chain triacylglycerols. Rauch et al. [23] let their subjects exercise for 5.5 h before a test-trial of 400 kJ taking ~20 min to complete for their well-trained subjects. Ingestion of fat led to a higher fat oxidation during the prolonged bicycling, but the performance of the time trial fell.

Dose of ingested MCT

We gave our subjects 24 g of MCT since that appeared to be the maximum tolerable dose, as judged from the unpublished pre-tests we did. Several other studies have used similar doses. In line with us Ivy et al. [8] and Décombaz et al. [3] have earlier found that 30 g of MCT may be the highest dose that may be ingested without frequent gastrointestinal pain. At the other extreme van Zyl et al. [26] used 86 g and reported no gastrointestinal pain. When Jeukendrup et al. [10] used the same MCT-dose, they reported that nausea and stomach pain occurred frequently. Goedecke et al., [5] gave one high (51g) and one low (26 g) dose of MCT and did not see any signs of gastrointestinal discomfort. Thus, it seems to be large variations in the maximum tolerable amounts of MCT-ingestion between subjects. It may be that those who can ingest large doses of MCT without problems may benefit from it. The mechanisms that regulate the tolerance of MCT-ingestion are not clear and may be a topic for further investigation.

We saw no adverse effects of the MCT-drink apart for one case of vomiting after the MCT-sprint. Thus, the MCT-drink used here may therefore serve as an alternative to traditional carbohydrate drinks.

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TWITCH POSTTETANIC POTENTIATION OF KNEE EXTENSOR MUSCLES AFTER BRIEF HIGH-FREQUENCY PERCUTANEOUS SUBMAXIMAL ELECTRICAL STIMULATION

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ABSTRACT

This study evaluated twitch posttetanic potentiation (PTP) of the human knee extensor (KE) muscles after brief (7-s) high-frequency submaximal percutaneous electrical stimulation. Thirteen young (aged 19–27 yrs) healthy men participated in this study. The subject sat on the dynamometric chair. To assess the twitch contractile properties of KE muscles, supramaximal percutaneous electrical stimulation of femoral nerve was used by rectangular pulses of 1-ms duration before and after submaximal tetanic contraction. Submaximal tetanic contraction (~25%MVC) of KE muscles with 7-s duration was evoked by direct percutaneous electrical stimulation by rectangular pulses of 0.3 ms at the frequency of 100 Hz. Twitch peak force (PT), maximal rates of force development (RFD) and relaxation (RR) potentiated immediately after tetanus by 12, 29 and 26%. respectively. PTP for PT and RFD was maximal (17 and 38%, respectively) 3 min after tetanus, and for RR 5 min after tetanus. No significant changes ($p>0.05$) in time-course characteristics in isometric twitch were found after tetanic stimulation. There was a significant negative correlation between pretetanic twitch contraction time and posttetanic PT after 10-min recovery, and RFD after 5-min recovery ($r=-0.56$ and $r=0.57$, respectively), i.e. a brief twitch was associated with greater twitch force potentiation.

Key words: posttetanic potentiation, knee extensor muscles, percutaneous electrical stimulation, twitch contraction

INTRODUCTION

Twitch potentiation is the enhancement of twitch force during and/or after repetitive electrical stimulation. Potentiation may be defined as staircase, observed during low-frequency stimulation, and posttetanic potentiation (PTP) is observed after a brief high-frequency tetanic stimulation [1, 9, 25]. PTP is greatest immediately after the tetanic stimulation and then decays rapidly but is still evident for ~10 min [9, 20]. PTP is often associated with a shortening of twitch contraction (CT) and half-relaxation (HRT) times [6, 20, 23] and increased rates of force development (RFD) and relaxation (RR) [5, 20]. The mechanism of PTP may be phosphorylation of myosin light chains during tetanic contraction, which renders actin-myosin more sensitive to Ca^{2+} in subsequent twitch [5, 21, 22, 26].

PTP has been shown in a variety of human muscles, including small hand muscles [10, 27], elbow flexors [13], knee extensors [6, 9, 25], and ankle dorsiflexors [20]. Muscles with the shortest twitch CT and HRT and highest proportion of fast-twitch fibers show the greatest PTP [2, 12, 19, 20]. The magnitude of PTP is influenced by the methods and conditions under which it is evoked. PTP is affected by the intensity, frequency, and duration of the conditioning tetanic stimulation [5]. The supramaximal percutaneous stimulation of the whole muscle at high frequency for ~5–10 s causes the greatest immediate PTP. However, supramaximal tetanic percutaneous nerve (indirect) or muscle (direct) electrostimulation could potentially induce muscle injury, pain, or discomfort [4]. Submaximal electrical stimulation less than 50% of the force produced during on maximal voluntary contraction (MVC) is often used in rehabilitation programs. In recent years, electromyostimulation training with high-frequency submaximal tetanic contractions has been used by athletes in the context of training programs to develop physical performance [15, 16]. However, the phenomenon of PTP in different human skeletal muscles after brief submaximal percutaneous electrical stimulation is not well investigated. Only few studies have been conducted to determine twitch potentiation after submaximal high-frequency or low-frequency percutaneous tetanic stimulation of human muscle.

The aim of the present study was to examine PTP in human knee extensor (KE) muscles after brief (7-s) high-frequency submaximal percutaneous electrical stimulation. We measured changes in force-generating and time-course characteristics of isometric twitch immediately and 10 min after a conditioning tetanic contraction at target force level of ~25% of maximal voluntary contraction (MVC) of KE muscles. Given that PTP is greater in faster contracting muscles, we measured whether there was a correlation between pretetanic twitch CT and relative increase in posttetanic twitch peak force (PT) and RFD, i.e. whether subjects with a briefer twitch tended to show greater PTP.

MATERIAL AND METHODS

Subjects

Thirteen healthy men (age 18–27 yr, height 168–194 cm, body mass 58–86 kg) volunteered to participate in the present study. They were physically active students with no history of neuromuscular disorders. After a routine medical examination, an informed written consent to participate was obtained. During the last 14 days before the study, the subjects were familiarized with the experimental setup. The study was approved by the University Ethics Committee for Human Studies.

Apparatus and Experimental Procedure

On reporting to the laboratory, the subject sat resting for ~ 30 min before the experiment for minimizing any potentiation effect from walking to the laboratory. During the experiment the subject sat on the custom-made dynamometer with the knee and hip angles equal to 90° and 110°, respectively [24]. The body position of the subject was secured by Velcro belts placed over the chest, hip and thigh. The unilateral knee extension isometric force of the dominant leg was recorded by standard strain-gauge transducer mounted inside a metal frame which was placed around the distal part of the ankle above the malleoli using a Velcro belt. The determination of the subject's dominant leg was based on a kicking preference. The electrical signals from the strain-gauge transducer were digitized on-line (sampling frequency 1 kHz) using a personal computer. The digitized signals were stored on a hard disk for further analysis.

To assess the contractile properties of KE muscles, electrically evoked twitches were elicited by indirect percutaneous electrical nerve stimulation. Prior to attaching the stimulating electrodes, electrode gel was applied to the contact surface, and the underlying skin was prepared by shaving, sanding and rubbing with isopropyl alcohol. Two commercially available carbon-rubber stimulating electrodes were used — the cathode (4x4 cm) placed on the skin over the femoral nerve in the inguinal crease and the anode (4x10 cm) placed over the mid-portion of the thigh. Elastic bandages were used to keep the electrodes in place and to ensure good electrode contact. The electrical stimuli were rectangular pulses of 1-ms duration applied at supramaximal intensity (130–150 V) delivered from an isolated voltage stimulator (Medicor MG-440, Hungary). To determine the supramaximal stimulation intensity, the voltage of rectangular electrical pulse was progressively increased to obtain a plateau in the twitch force, i.e. when twitch force failed to increase despite additional increases in stimulation intensity. The same stimulation intensity (~20% greater than that needed for maximal twitch response) was further used for twitches evoked before the tetanic stimulation and during the recovery period. The following characteristics of isometric twitch were calculated: PT — the highest value of isometric force production, CT–

the time to twitch peak force, HRT — the time of half of the decline in twitch peak force, RFD — the first derivate of the development of force (+dF/dt) and RR as the first derivate of the decline of force (-dF/dt).

Two min after the pretetanic testing of twitch contraction had been established, MVC force of KE muscles was measured. The subject was asked to exert maximum voluntary isometric knee extension against the belt of the strain-gauge transducer as forcefully as possible during approximately 3 s. Three maximal attempts were recorded and the best result was taken for further analysis. A rest period of 2 min was allowed between the attempts.

Two min after MVC force testing tetanic stimulation voltage for target level of force at 25%MVC was determinated and controlled by two separated stimulations with 2 s duration. A portable battery-powered stimulator (Compex, Medicompex SA, Ecublens, Switzerland) was used. Three 2 mm-thick, sel-adhesive electrodes were placed over thigh. The positive electrodes (5 cm x 5 cm), which had membrane depolarizing properties, were placed to the motor point area of vastus lateralis and vastus medialis muscle and near the proximal insertion of each muscle. The negative electrode (5 cm x 10 cm) was placed over the proximal-portion of the thigh between stimulating electrodes for twitch measurements. Rectangular voltage pulses of 0.3-ms duration at the frequency of 100 Hz were used. The stimulation voltage was calculated for each subject prior to the testing, according to individual force response. After 15 min resting the submaximal tetanic contraction (approximately 25%MVC) of KE muscles of 7-s duration was evoked by direct percutaneous electrical stimulation. After the end of tetanic stimulation, the subject remained seated without moving his legs for a recovery period of 10 min. The posttetanic testing of isometric twitches was performed immediately (5 s) after tetanic stimulation, and 1, 3, 5 and 10 min after tetanic stimulation. The decrease in force during 7-s stimulation was determined.

Statistics

Data are means and standard errors of the mean (±SEM). One-way analysis of variance (ANOVA) followed by Scheffe post hoc comparisons were used to test for differences between pre- and posttetanic values. Linear correlations were calculated to assess the relationship between posttetanic potentiation and pretetanic twitch characteristics. A level of $p<0.05$ was selected to indicate statistical significance.

RESULTS

Pretetanic twitch contractile properties. The isometric twitch PT was 63.8±3.5 N, and CT and HRT were 80.3±4.1 and 85.2±5.2 ms, respectively. Twitch maximal RFD and RR were 526.1±2.7 and 265.5±18.7 $N \cdot s^{-1}$, respectively.

Posttetanic twitch contractile properties. Tetanic force decreased by 21% during the 7-s tetanic stimulation. Figure 1 shows posttetanic changes in twitch contractions during 10-min recovery period. Twitch PT, RFD and RR potentiated immediately after tetanus by 12, 29 and 26%, respectively. PTP for PT and RFD was maximal (17 and 38%, respectively) 3 min after tetanus, and for RR 5 min after tetanus. Ten min after tetanus twitch PT, RFD and RR was potentiated by 12, 24 and 20%, respectively. The potentiation for PT, RFD and RR was significant ($p<0.05$) throughout the 10-min recovery period. No significant changes ($p>0.05$) in time-course characteristics in isometric twitch (CT and HRT) were found after tetanic stimulation as compared to pretetanic level. There was a significant ($p<0.05$) negative correlation between pretetanic twitch CT and posttetanic PT after 10-min recovery, and RFD after 5-min recovery ($r=-0.56$ and $r=0.57$, respectively), i.e. a brief twitch was associated with greater twitch PTP.

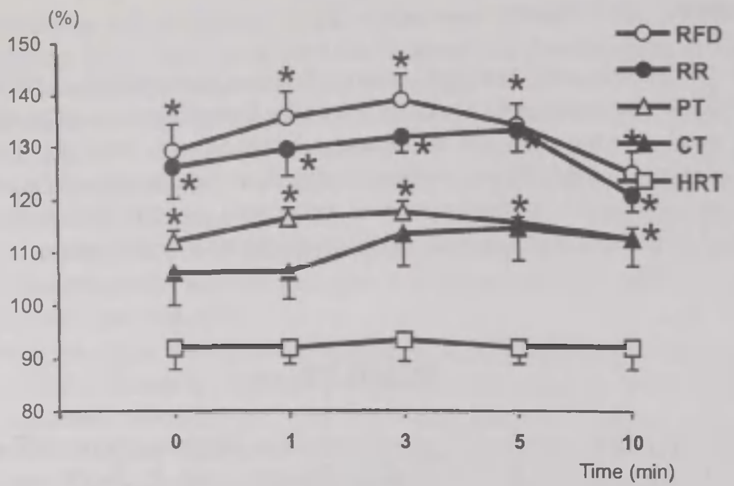

Figure 1. Changes in isometric twitch characteristics after a 7-s high-frequency percutaneous tetanic stimulation at target force level of 25% MVC. Values, expressed as percentage of pretetanic value (dashed line), are means±SEM for 13 subjects. MVC — maximal voluntary contraction, RFD — rate of force development; RR — rate of relaxation, PT — peak force, CT — contraction time, HRT — half-relaxation time. * Significantly different ($p<0.05$) from pretetanic value.

DISCUSSION

The present study indicated that twitch force-generating parameters (PT. RFD and RR) were markedly potentiated immediately after a 7-s high-frequency submaximal tetanic stimulation and during 10 min of recovery period. The decay in PTP from the immedial posttetanic value was not a simple exponent function, as sometimes observed [9, 12, 13]. In this study, PTP showed after tetanic stimulation a small increase at 1, 3, and 5 min followed by a small decrease at 10 min. O'Leary et al. [20] observed that PTP in dorsiflexor muscles declined over the 1st min after 7-s supramaximal tetanic stimulation at the frequency of 100 Hz but then showed a small increase at 2 min before it decreased again. This triphasic pattern of decay has been shown after MVC-s by several investigators [6, 10, 28]. Several investigators have suggested that a increase in twitch potentiation is caused particularly by fatigue; as fatigue wanes, the level of potentiation increases before falling away [28]. Fatigue may have been a factor in the present study, since tetanic force decreased by 21% during the 7-s submaximal percutaneous stimulation. It has been shown that tetanic force failure during electrostimulation at frequency of 100 Hz results an impaired propagation of muscle action potentials with no metabolis changes [3].

The mechanism of twitch potentiation involves excitation-contraction coupling and/or myosin-actin interaction, rather than amplified excitation of muscle, i.e. enlarged muscle action potential [9, 5]. Potentiation is caused by phosphorylation of the regulatory light chains of myosin, a Ca^{2+}-dependent process [22, 26]. However, it has been shown that the muscle compound action potential (M-wave) increased sharply at 2 min after high-frequency tetanic stimulation and then subsided [20]. The M-wave amplitude may also enlarge after low-frequency tetanic stimulation or brief MVC-s [7, 8, 17]. The mechanism of M-wave potentiation is due to stimulation of the sarcolemma's Na^+-K^+ -pumping mechanism [17]. A large muscle action potential might increase Ca^{2+} release from the sarcoplasmic reticulum, thereby increasing force.

The present study indicated that after tetanic stimulation a relative potentiation was greater for twitch RFD and RR rather than for PT (with peak values of 38, 32 and 17%, respectively). The RFD has rarely been used as an indicator of muscle contraction speed and probably depends largely on the rate of formation of cross-bridges between myosin and actin during contraction [14]. The RR is an indicator of muscle relaxation speed and depends on the rate of re-attachment of cross-bridges during relaxation process [11, 28]. Our results showed that these intracellular processes are highly affected by PTP. In this study, the potentiated twitch had a little increased CT and decreased HRT. However, the posttetanic changes in these time-course characteristics of isometric twitch were not significant. This is controversial to several previous studies which have indicated a significant decrease in twitch CT and/or HRT during PTP in human muscles [13, 20] and animal muscles [18, 21]. These differences may be related to different stimulation protocol and muscles. The CT and HRT are related to Ca^{2+}

release from and reuptake by sarcoplasmic reticulum, respectively. The present results indicated that these intracellular processes were only slightly affected by PTP during submaximal percutaneous electrical stimulation.

We found a negative correlation between pretetanic twitch CT and posttetanic relative increse in twitch PT at 10 min and in RFD at 5 min: subjects with a shorter twitch CT tended to have a greater PTP. By O'Leary et al. [20] has also been found that twitch PTP after brief high-frequency tetanic stimulation was significantly negatively correlated with pretetanic CT (r=–0.69). These results are in agreement with previous studies indicating greater PTP in fast contracting muscles consisting of a high percentage of fast-twitch fibers [2, 12, 19]. It has been shown that greater PTP in fast-twitch fibers may be related to their greater capacity for myosin phosphorylation in response to a tetanic contraction [5].

In conclusion, this study indicated a moderate potentiation of force-generating characteristics of the isometric twitch of KE muscles after brief high-frequency percutaneous submaximal tetanic stimulation with small increase at 1–5 min followed by decreased at 10 min. However, no significant changes in time-course characteristics of twitch have been observed. A brief pretetanic twitch was associated with greater twitch posttetanic force potentiation.

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VALUE ORIENTATION OF FULL-TIME, EXTRA-MURAL AND POST GRADUATE STUDENTS OF PHYSICAL EDUCATION IN POLAND

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ABSTRACT

In the presented paper there is led an analysis of opinions concerning four types of typical physical education classes: plays and games, gymnastics, team sports and track and field classes. For the research 10 point-scale Value Orientation Inventory was used. Theoretical framework was based on various definitions of physical education in literature and research reviews, which allowed for development of five value orientations most characteristic for typical physical education setting in curricular decision making: *physical activity, physical fitness, disciplinary mastery, learning process, moral education.* Students of three different forms of studying (full-time n=200, extra-mural n=60, post-graduate n=165) were examined to establish how they acknowledge lesson goals and form their expectations.

Results proved that the independent variable — form of studying, strongly influenced the goals the students set for the four types of physical education classes in most of the examined value orientations, which led to the conclusion of significant differences between students gaining the same qualification in three different forms.

Key words: physical education, value orientation, teacher preparation

INTRODUCTION

Physical education, which according to British scientists [5] have recently been pushed out into defensive position in areas of time-table, budget and stuff lacks on social status. It is often the case that having the same qualifications teachers differs in knowledge, methodological skills and pedagogical preparation.

Physical education should aim at development of motor and somatic features at particular age, as well as at preparation to life-long cultivation of one's health. The first of the mentioned aims is due to school education in area of human kinetics, the second deals with pedagogically-based development of health-related attitudes. Osiński [7] believes that physical education is a deliberate action directed on shaping attitudes in pupils, through passing information, building up motor abilities and sporting skills, all of which set categories of human physical culture and therefore influences process of teaching/learning and its effectiveness.

In previous research Gracz [4] has constructed a prototype of sporting situation in professional sport. In sport, a prototype of typical situation based on a Magnusson-Lendler theory Gracz [4] included five dimensions: *maximalization, public perception, competitiveness, duration of training process* and *physical activity* proving their statistical correlation and influences in various sports. The purpose of all situations in professional sport is directed towards transformation of the initial situation of sport for all sporting level of numerous young talents into top sport level of selected individuals, securing possible success at national and international level. In case of physical education, an obligatory subject of school education, aims should consider needs and interests of all pupils within their genetically determined motor abilities and socially determined intellectual capacity, despite the level they represent. This puts school physical education in an entirely different position than sport.

An analysis of subject-connected literature indicated some major differences between programs, their implementation and evaluation of teaching/learning process in methodology of teaching physical education in Poland and some European countries [1, 2] or the USA [3, 8]. There are five dimensions listed in English-speaking countries in research on the same problem of value orientation of pre-serviced teachers (*disciplinary mastery, self-actualization, learning process, social reconstruction* and *ecological integration).*

The differences in value orientations are not only due to differences in curricula and educational traditions, but also indicate how strong influence on education may the cultural and social aspects have in various countries. Solmon et al. [8] proved in their research that American students of physical education begin studying with strong value orientations and visions of a typical physical education lesson, which do not change throughout the studies nor afterwards. Interestingly Curtner-Smith and Meek [2] proved no differences between male and female students in perception of physical education classes, and *disciplinary mastery* appeared to be the most important value orientation.

Curriculum theorists believe that value systems or orientations that teachers bring to the curricular decision-making process, determine their goals for students learning and academic and behavioral expectations for success [6].

The main idea of the research was to generate dimensions characteristic for physical education classes all over the world, not only in setting typical for American culture or any other. The work aimed at finding out the answer to the question: Do all type of physical education students have the same value orientations, since their gain the same formal qualifications in three different forms of studying? Such question remains important also for the training of perspective PE teachers.

MATERIAL AND METHODS

The research examined value orientations within physical education among PE regular (n=200) and extramural (n=60) students of Faculty of Physical Education and students (n=165) of post-graduate Physical Education Teacher Training courses of three University Schools of Physical Education in Poznań, Wroclaw and Gdańsk. For the research 10 point-scale Value Orientation Inventory was used. Theoretical framework was based on various definitions of physical education in literature and research reviews, which allowed for development of five value orientations most characteristic for typical physical education setting in curricular decision making: *physical activity, physical fitness, disciplinary mastery, learning process, moral education.* Students were examined to establish how they acknowledge lesson goals and form their expectations.

Value orientations represent certain philosophical perspective, which can be operationalized as educational goals for student learning. There are several value perspectives that may affect curricular decision-making; however, not all of them are common for all typical physical education settings in most countries with highly developed education systems. These factors influence the teachers' emphasis on the learner, the context and the knowledge passed on pupils. In our research goals of physical education were grouped in five value orientations. Through the *disciplinary mastery* teachers expect learners to exhibit proficiency in a variety of sports and maintain as acceptable level of fitness. In the *learning process* orientation of goals of the curriculum emphasize the nature of learning using a variety of content. The main point of the process is on learning how to learn, teachers and pupils divide tasks into separate components and go through each of them in details. The *physical activity* value focuses on undertaking variety of forms of physical activity both in and out-side school setting, as a preparation to life-long participation in physical culture. This value is concerned with passing the knowledge and teaching the skills enabling pupils for further participation and self-development in sports and other forms of health care. In the *physical fitness* goals emphasis development of motor abilities and the main focus is on simple stimuli-reaction model of learning and testing motor performances. Education without moral aspects would be incomplete and therefore the fifth value orientation the *moral education* is concerned with humanistic development of man, with taking all actions necessary for shaping lasting attitudes towards life-long participation in physical culture.

Data were analyzed using comparison of variance of F-test, where dependent variable was the form of studying (full-time, extra-mural and post-graduate) and independent variables were four types of physical education classes — plays and games, gymnastics, sport games and track and field classes.

RESULTS

An analysis of data in Table 1 proved statistically significant differences at the level of $p \leq 0.001$ in most of the examined independent variables for three forms of studying: full-time, extra-mural and post graduate.

Table 1. Comparison of the F-test results of analyses for five value orientations in four types of physical education classes.

Class type \values	Physical activity	Disciplinary mastery	Learning process	Physical fitness	Moral education
Gymnastics	10.04012**	1.38361	5.29428**	8.21706**	4.34765*
Plays and games	18.58882**	2.34429	7.13460**	9.92092**	10.85962**
Track and Field	6.35520**	10.51684**	6.99242**	8.52561**	5.15603**
Team sports	2.26456	2.96631	2.67360	4.89652**	9.00206**

**$p \leq 0.01$, *$p \leq 0.05$

Form of studying appeared to be an important dependent variable in shaping students' value orientations. Value *physical activity* differentiated results in case of classes of gymnastics, plays and games as track and field. No significant differences were noticed in classes of team games. In opinion of examined student's value called *disciplinary mastery* was equally important in all classes except for track and field types of classes. An analysis of mean figures in *learning process* value indicated statistically significant differences in case of gymnastics, plays and games classes and in track and field. Both *physical fitness* and *moral education* values proved to be considered differently by full-time, extra-mural and post-graduate students in all four types of physical education classes. The differences were statistically significant at the level of $p \leq 0.001$, except for the class of gymnastics where the level of significance was at the level of $p \leq 0.05$ in *moral education* value orientation.

Form of studying appeared to be the strongest variable significant at the level of $p \leq 0.05$ in case of following value orientation: *disciplinary mastery* in classes of plays and games (F=18.58**) and in classes of track and field (F=10.52**), *physical activity* in classes of gymnastics (F=10.04**) and *moral education* in classes of plays and games (F=10.85**). The lowest significance was found in case of *disciplinary mastery* value orientation in classes of gymnastics (F=1.38).

The aim of the examined pre-serviced physical education students was to indicate how important was each of the five value orientation in four types of physical education classes. Underneath there are presented on graphs mean figures of students from three forms of studying in four types of classes (Figure 1).

In a class of games and plays both full-time (M=6.63) and extra-mural (M=7.98) students pointed at *moral education* value orientation as the most important, which is in accordance with a theory of play, as well as with the traditional role plays and games used to have in process of physical education learning (especially among early stages of children up-bringing). Post-graduate believed that the most important thing in such classes should be *physical activity* (M=7.89). According to reform of education system introduced in Poland in year 1999 firstly we should educate then educate physically. Statistically significant differences at the level of $p \leq 0.001$ have been noticed between full-time and extra-mural students and extra-mural and post graduate students in *learning process* and *physical fitness* (Figure 1).

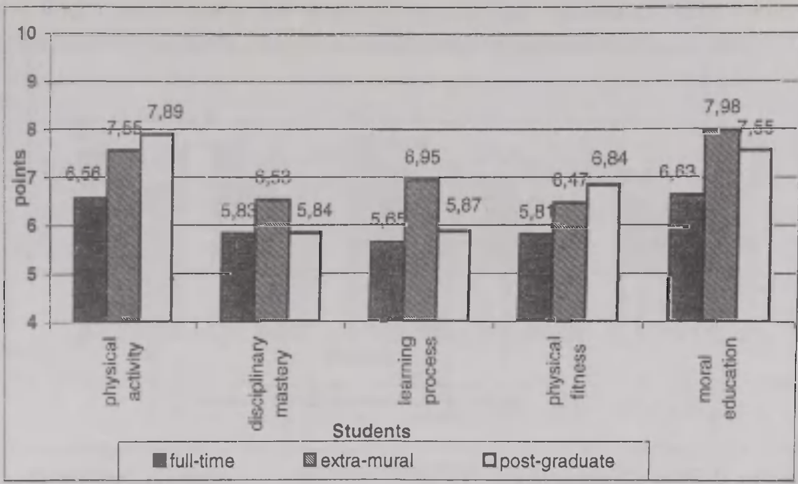

Figure 1. Mean figures in five value orientations in a class of games and plays.

In a class of gymnastics full-time and extra-mural students seem to have a common viewpoint that the most important value orientation should be here *learning process.* Since there is dangerous equipment used very often this specific type of physical education classes requires concentration, discipline and obedience provided mainly through well-organized and planned lessons. Post-graduate students pointed at *physical fitness* (M=7.44), which was believed to be a needed dose of biological "load". This opinion reminds us of traditional stereotype of physical education in Poland. Except for *disciplinary mastery* in all the others value orientations there were significant differences observed among students of all forms of studying, which indicates how differently the goals of this type of classes are seen among students (Figure 2).

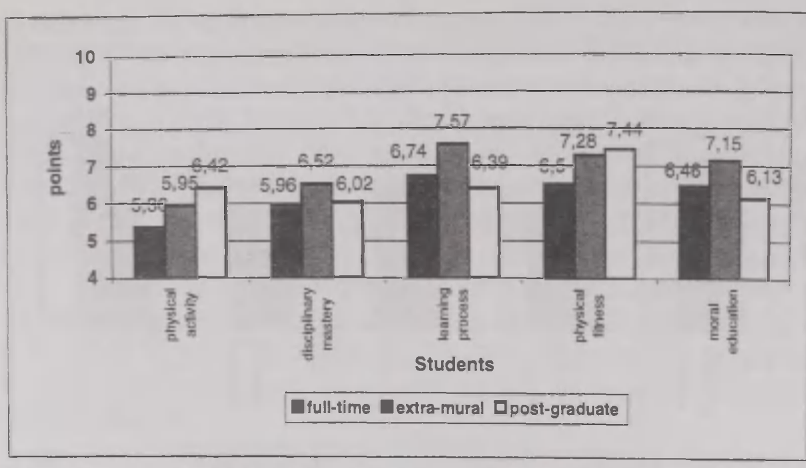

Figure 2. Mean figures in five value orientations in a class of gymnastics.

In team sports classes containing a full range of emotional contexts during rivalry competition the most important value orientation for all types of students was preparation for life-long participation within physical culture — *physical activity* (Figure 3). An analyses of the results showed that there were differences at the level of $p \leq 0.001$ in *physical fitness* and *moral education* values in opinions of full-time, extra-mural and post-graduate students. This might be caused by the extended term "team sports", which consists of basketball, volleyball, football, handball and field hockey. On the other hand it is team sports, which provide the biggest opportunity to spend leisure time actively and preparation to life-long sports still remains the major goal of school physical education.

In classes of track and field an analyses of opinions of students showed significant statistical differences at the level of $p \leq 0.001$ in all the value orientations. (Figurey) In all cases there was a significant difference between full-time students and the others. Developing *physical fitness* was more important for extra-mural (M=7.98) and post-graduate (M=7.86) students than for full-time students (M=7.11). All students believed that *physical activity* value orientation should be of the high importance in organizing athletic activities. The lowest importance was given to the value of *disciplinary mastery*.

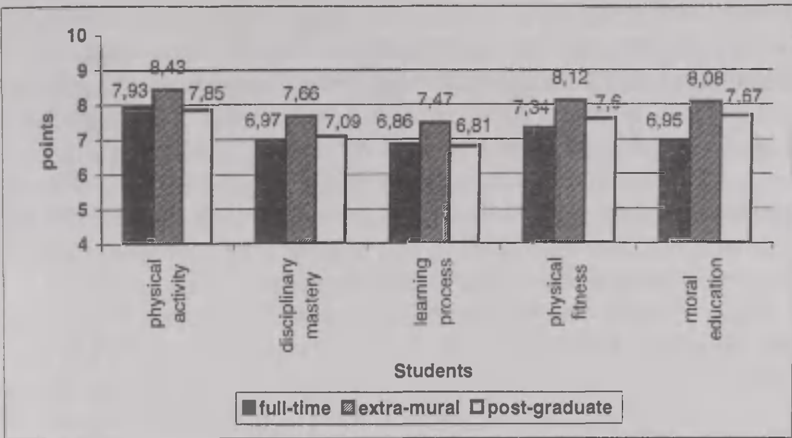

Figure 3. Mean figures in five value orientations in a class of team sports.

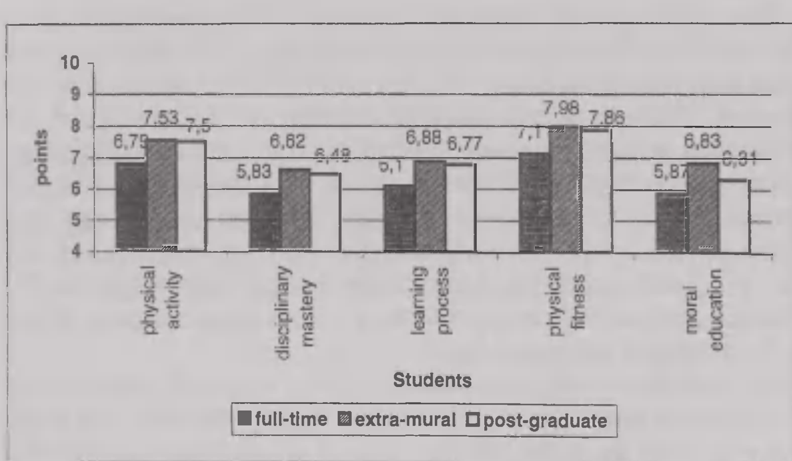

Figure 4. Mean figures in five value orientations in a class of track and field.

DISCUSSION

Planning a 45-minutes physical education lesson a teacher considers thematic needs regarding educational and motor aims, according to which he chooses contents and realization methods for particular tasks. Effectiveness of the teaching/learning process depends on many factors among which teacher's experience, his professional preparation, style of teaching, personality and general conditions of teaching influence the process the most. However, the key to effective teaching seems to be in the subject — in the pupil, recognition of his needs, interests and motor abilities. It is equally important to provide an appropriate level of intensity and adjust the pace of learning to the pupils' capacities.

In our research the goals of a single physical education lesson were seen differently by students studying as full-time, extra-mural and post-graduate. Statistically significant differences in all three groups, noticed at the level of $p \leq 0.001$ in examined value orientations allowed for conclusion of meaningful dissimilarities between programs of Physical Education Teacher Training at Universities in Poznań, Gdańsk and Wrocław.

The lowest mean figure in all groups was observed in value orientation *disciplinary mastery*, connected with basic knowledge and skills in pursuit of excellence and self-development in sphere of human physical efficiency. Unfortunately, students did not recognize the preparation towards life-long lasting physical culture participation, which school physical education should provide. Generally it was noticed that full-time students are better prepared educationally and methodologically than students of other forms of studying and they have reasonable professional knowledge to start work in schools. The full-time students had more consistent opinions about the goals of four types of physical education classes.

To evaluate or compare classes of physical education, teachers need to workout common "tools" of evaluation both at the level of a single lesson as well as at the level of general effectiveness of curricula, especially in health-related behavior and attitudes. The results of the research led to a conclusion that there is more pedagogical and methodological preparation required for all types of PE students and this should be more connected with the praxis in "practice schools".

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EFFECT OF 4-WEEK REHABILITATION ON SHOULDER FUNCTION IN PATIENTS WITH FROZEN SHOULDER

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ABSTRACT

This study evaluated the effect of 4-wk rehabilitation in combination with exercise therapy, massage and electrical therapy on shoulder function in patients with frozen shoulder (FS). Ten FS patients of mean age of 50.2±4.6 yrs and 10 healthy control subjects of mean age of 49.8±4.6 yrs participated. Standard goniometric measurements were used to assess shoulder flexion and abduction, and internal and external rotation active range of motion (ROM). Maximal voluntary isometric strength of the shoulder abductors and external rotators was measured by hand-held dynamometer. In FS patients, the shoulder flexion and abduction, internal and external rotation active ROM, isometric strength of the shoulder abductors and external rotators for involved extremity were significantly lower before rehabilitation as compared to healthy controls. The shoulder flexion and abduction active ROM for involved extremity in FS patients increased significantly with 4-wk of rehabilitation. No significant changes in shoulder internal and external rotation active ROM, and in isometric strength of the shoulder abductors and external rotators for involved extremity in FS patients were observed with rehabilitation. It was concluded that 4-wk rehabilitation program was moderately effective for improvement of the shoulder function in FS patients.

Key words: shoulder joint, range of motion, shoulder muscle isometric strength, frozen shoulder

INTRODUCTION

Shoulder joint is a complex joint that is crucial to many activities of daily living (ADL). As a functional joint, the human shoulder joint permits movements in all degrees of freedom and is, unlike the other joints, nearly completely stabilized by the surrounding musculature [7]. The shoulder problems have been highlighted by several researchers [1, 10, 13], and there is evidence that their prevalence may be rising [16]. Frozen shoulder (FS) or adhesive capsulitis or shoulder periarthritis affects 2–5% of the population and is most common in the 40–60-year-old age group [19]. FS is characterized by an insidous and progressive loss of active and passive mobility in the glenohumeral joint, presumably due to capsular contracture [15]. Despite intensive research, the etiology and pathology of FS remain unclear [4]. Frequent or sustained shoulder elevation at above 60° in any plane during occupational task has been identified as a risk factor for the development of shoulder traumatic injuries, nonspecific shoulder pain and FS [8, 14]. Pain of the shoulder region often keeps FS patients from performing ADL. Many FS patients complain of sleeping disorders due to pain and their inability to lie on the affected shoulder [18]. FS results in a gradual loss of shoulder range of motion (ROM) and strength of surrounding muscles [9, 11]. The increase in the shoulder active ROM and strength of the shoulder muscles is an important component for the reduction of physical disability and improvement of the shoulder function in FS patients during rehabilitation [17]. The rehabilitation of FS patients is frequently prolonged despite multiple therapeutic maneuvers. The rehabilitation program of FS patients commonly includes exercise intended to restore normal shoulder kinematics and/or shoulder muscle activity.

The present study was designed to investigate the effect of 4-wk rehabilitation in combination with exercise therapy, massage and electrical therapy on shoulder function in FS patients. More specifically, we were interested in examining the shoulder active ROM in four different degrees of freedom (flexion, abduction, internal and external rotation) and maximal voluntary isometric strength of the shoulder abductors and external rotators in FS patients for involved and uninvolved extremity before and after the rehabilitation program. All characteristics of FS patients were compared with those of the healthy control subjects.

METHODS

Subjects

Two groups of subjects participated in this study: (1) 10 FS patients (7 women and 3 men) and (2) 10 healthy age- and gender-matched control subjects (7 women and 3 men). The physical characteristics of the subjects are presented in Table 1. FS was diagnosed by a physician. Patients were asked to fill the questionnaire in regard to the presence of shoulder pain and difficulties in ADL. The period of shoulder pain for patients before the rehabilitation was from 2 weeks to 3 months. The subjects were moderately physically active, and no professional athletes were included. They had no orthopedic or neurological limitations or contraindications for exercise testing or training. The 4-wk rehabilitation program for all FS patients was performed by the same physiotherapist in the Centre of Sports Medicine and Rehabilitation at Tartu University Hospital. The rehabilitation program consisted of 10 exercise therapy procedures in gymnasium and swimming pool with the duration of 30 min/day, 5–10 massage procedures with the duration of 20 min/day and 5–10 electrical therapy procedures with the duration of 10 min/day. In FS patients, shoulder active ROM and isometric strength characteristics for involved and uninvolved extremity were tested before and after 4-wk rehabilitation. These characteristics were measured in control subjects once. Subjects were informed about the procedures and their written consent was obtained. The study carried the approval of the Ethics Committee of the University of Tartu.

Table 1. The physical characteristics of the subjects

Subject	Gender	Age (years)	Height (cm)	Body mass (kg)	BMI (kg·m^{-2})
FS patients					
1	F	52	164.5	71.0	26.4
2	F	55	164.0	80.0	29.7
3	F	48	172.8	79.9	26.7
4	F	62	161.4	59.7	23.0
5	F	51	160.0	56.3	21.9
6	F	60	159.0	78.0	30.8
7	F	34	168.2	60.5	21.4
8	M	18	178.0	73.0	23.0
9	M	68	173.5	72.2	24.1
10	M	55	181.2	95.9	29.2
Mean±SE		50.2±4.6	168.7±2.8	72.7±3.8	25.6±1.0
Controls					
1	F	51	160.6	113.2	44.2
2	F	49	159.3	85.2	33.7
3	F	35	176.0	100.0	32.3
4	F	63	162.5	82.1	31.3
5	F	49	155.5	59.8	24.9
6	F	63	167.0	72.0	25.8
7	F	56	164.3	64.0	23.8
8	M	18	180.0	70.0	21.6
9	M	66	168.5	63.0	22.3
10	M	55	179.0	105.0	32.7
Mean±SE		49.8±4.6	167.3±2.7	81.4±6.0	29.4±2.2

BMI — body mass index; FS — frozen shoulder

Apparatus and Experimental Procedure

We gave the subjects instructions and demonstrated the shoulder active ROM and strength testing procedures 24–48 hours before collecting of the first data. This was followed by a practical session to familiarize the subjects with the procedures. Before testing, each subject underwent a 10-min warm-up by gymnastics and stretching exercises.

The shoulder flexion and abduction, and internal and external rotation active ROM were measured by gravitational goniometers (Bubble Inclinometer, Fabrication Enterprices Inc., USA and Myrin, Follo A/S, Norway). Subjects were positioned standing for all ROM tests according to standard guid-lines [12]. All assessments were performed by the same physiotherapist.

Isometric manual muscle tests were performed to evaluate maximal voluntary isometric strength of the shoulder abductors and external rotators using a hand-held dynamometer (Lafayette Manual Muscle Test System, Lafayette Instrument Company, USA). During strength testing the subject was in a seated position on standard chair. During shoulder abduction strength assessment the full extended upper extremity was positioned with the shoulder abducted to 45°. Hand-held dynamometer was placed laterally on the distal end of the humerus approximately 5 cm above to elbow joint. Shoulder external rotation strength assessment was performed with the shoulder in vertical position and the elbow flexed to 90°. Hand-held dynamometer was placed laterally on distal part of elbow approximately 5 cm above to wrist. The forearm was pronated during all strength tests. The positions were carefully supervised by the physiotherapist and the subjects were encouraged to act in the desired way. Subjects were required to exert a voluntary isometric contraction pushing against the dynamometer for approximately 3 s. Before each contraction, subjects were instructed to "push as forcefully as possible". The best result from 3 attempts was taken as isometric maximal voluntary strength. A rest period of 1 min was allowed between attempts. All shoulder muscle strength assessments were performed by the same physiotherapist.

Data Analysis

Data are means and standard errors (±SE). One-way analysis of variance (ANOVA) for repeated measures followed by Tukey *post hoc* comparisons was used to evaluate differences between the groups and between involved and uninvolved extremity, and between different testing periods. A level of $p<0.05$ was selected to indicate statistical significance.

RESULTS

Before the rehabilitation, FS patients showed a significant reduction ($p<0.05$) in the shoulder flexion and abduction active ROM for involved extremity compared with uninvolved extremity and to controls (Fig. 1A, B). After 4-wk rehabilitation, there was a significant increase ($p<0.05$) in the shoulder flexion and abduction active ROM in FS patients for involved extremity as compared with pre-rehabilitation level. However, after the rehabilitation, the shoulder flexion and abduction active ROM for involved extremity in FS patients remained significantly lower ($p<0.05$) compared with uninvolved extremity and to controls. Before the rehabilitation, FS patients showed a significant reduction ($p<0.05$) of the shoulder internal and external rotation active ROM for involved extremity compared with controls (Fig. 1A, B). There were no significant differences ($p>0.05$) in the shoulder internal and external rotation active ROM for involved and uninvolved extremities in FS patients before the rehabilitation. The shoulder internal and external rotation active ROM for involved extremity in FS patients remained unchanged ($p>0.05$) with rehabilitation.

Before the rehabilitation, FS patients showed a significant reduction ($p<0.05$) in the isometric maximal voluntary strength of the shoulder abductors and external rotators for the involved extremity compared to controls (Fig. 2). Maximal voluntary isometric strength of the shoulder abductors and external rotators for involved extremity in FS patients did not change significantly ($p>0.05$) with 4-wk rehabilitation.

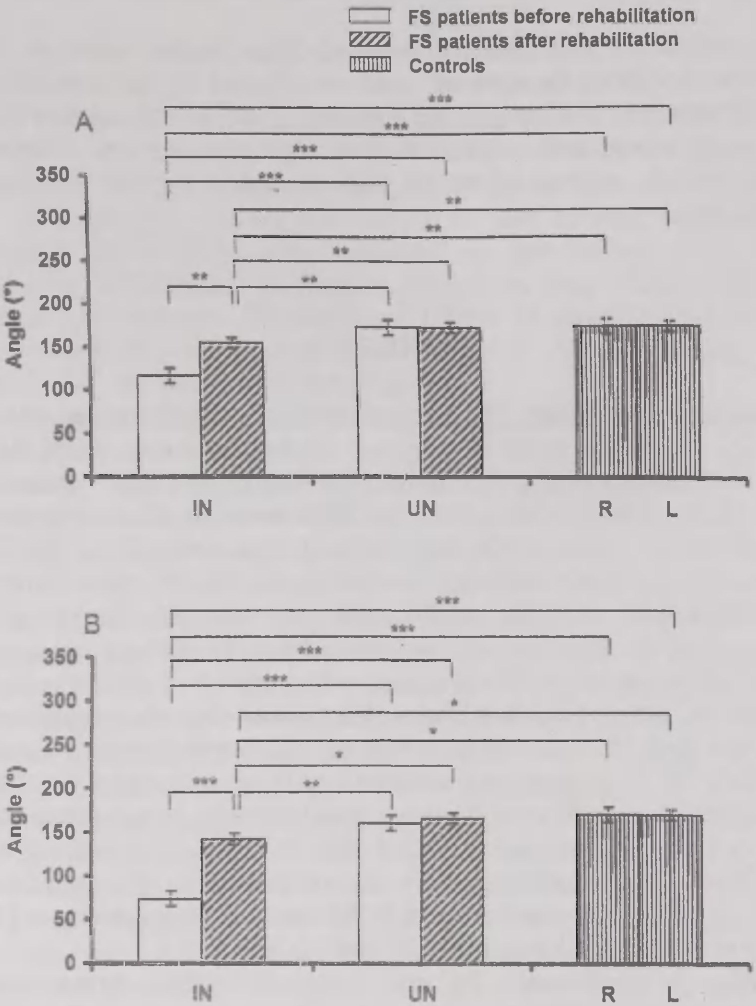

Figure 1. Mean (±SE) shoulder flexion (A) and abduction (B) active range of motion in patients with frozen shoulder (FS) before and after 4-wk rehabilitation and in controls. IN — involved extremity; UN — uninvolved extremity; R — right extremity; L — left extremity. * $p<0.05$: ** $p<0.01$; *** $p<0.001$.

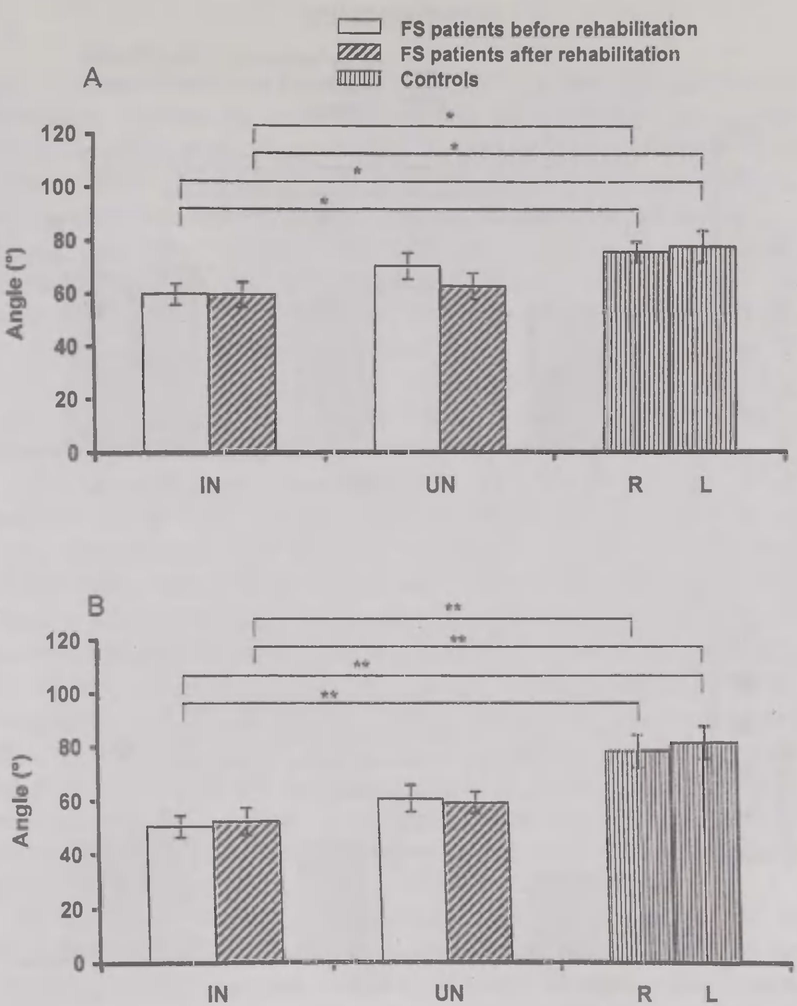

Figure 2. Mean (±SE) shoulder internal (A) and external (B) rotation active range of motion in patients with frozen shoulder (FS) before and after 4-wk rehabilitation and in controls. IN — involved extremity; UN — uninvolved extremity; R — right extremity; L — left extremity. * $p<0.05$: ** $p<0.01$.

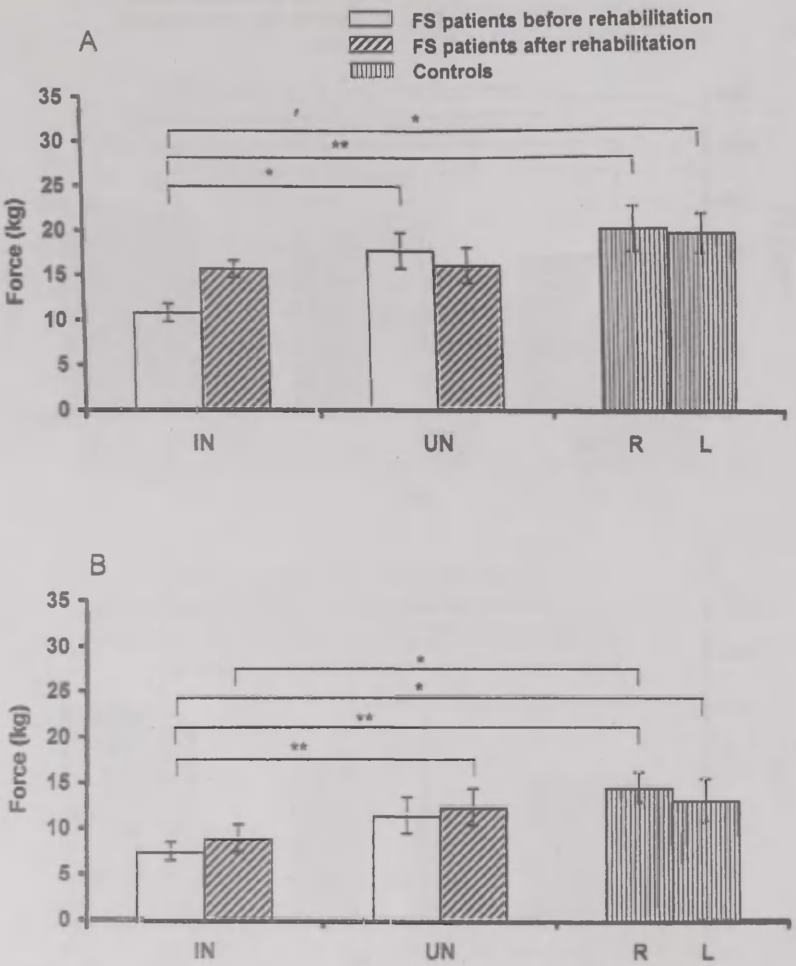

Figure 3. Mean (±SE) maximal voluntary isometric strength of the shoulder abductors (A) and external rotators (B) in patients with frozen shoulder (FS) before and after 4-wk of rehabilitation and controls. IN — involved extremity; UN — uninvolved extremity; R — right extremity; L — left extremity. * $p<0.05$: ** $p<0.01$.

DISCUSSION

The results of the present study indicated that the shoulder flexion, abduction, internal and external rotation active ROM for involved extremity (with mean values of 117, 74, 60 and 51°, respectively) in FS patients before the rehabilitation was significantly lower as compared with uninvolved extremity and to controls. Mean values of the shoulder flexion, abduction, internal and external rotation active ROM for healthy subjects are 180, 180, 80 and 80°, respectively [5]. The present study demonstrated 35, 59, 25 and 37% less shoulder flexion, abduction, internal and external rotation active ROM, respectively, for involved extremity in FS patients compared with values of healthy subjects. Several investigators have described a reduced shoulder active ROM in different degrees of freedom in FS patients [2, 3, 6, 18].

The present study demonstrated a significant increase in the shoulder flexion and abduction active ROM (mean values of 155 and 147°, respectively) for involved extremity in FS patients with rehabilitation. This is in agreement with data of Griggs et al. [6], who found a marked increase in the shoulder flexion active ROM in FS patients with rehabilitation. One possible explanation for the increase in the shoulder flexion and abduction active ROM in patients after the treatment is a decreased pain by multiple therapeutic maneuvers (massage, electrical stimulation, exercise). The present results indicated that the shoulder internal and external active ROM in FS patients for involved extremity did not change significantly following the 4-wk rehabilitation. Thus, the FS patients have to undergo additional rehabilitation procedures for the improvement the shoulder active ROM.

FS is characterized by significantly decreased strength of the shoulder muscles [9]. In this study, FS patients demonstrated 45 and 48% less ($p<0.05$) maximal voluntary isometric strength of the shoulder abductors and external rotators for involved extremity, respectively, before the rehabilitation compared to controls. FS was accompanied by pain and the patients tried to use the hand sparingly. It has been shown that ADL was markedly decreased in FS patients as compared to healthy subjects [18]. The decreased physical activity and shoulder immobilization are important factors of shoulder muscle atrophy and decreased strength. The present study did not indicate a significant change in maximal voluntary strength of the shoulder abductors and external rotators in FS patients with 4-wk rehabilitation. It seems likely that special exercises at higher intensity and/or longer duration are required for a significant improvement of the shoulder muscle strength in FS patients.

In conclusion, the present study demonstrated that 4-wk rehabilitation program in combination with exercise therapy, massage and electrical therapy improved the shoulder flexion and abduction active ROM without a significant change in shoulder internal and external rotation active ROM, and maximal voluntary isometric strength of the shoulder abductors and external rotators in FS patients. The shoulder pain and difficulties in ADL decreased in FS patients with rehabilitation. This rehabilitation program was moderately effective for the improvement of shoulder function in FS patients. Exercise therapy at higher intensity and/or duration in combination with other treatment maneuvers is required for more significant changes in shoulder muscle strength and shoulder active ROM in FS patients.

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EFFECT OF LOW-RESISTANCE STRENGTH TRAINING ON NEUROMUSCULAR FUNCTION IN YOUNG MALE CROSS-COUNTRY SKIERS

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ABSTRACT

The present study evaluated the effect of low-resistance strength training on maximal voluntary contraction (MVC) force and twitch contractile properties of the knee extensor (KE) and plantarflexor (PF) muscles in young cross-country skiers. Nine male skiers with mean age of 15.2±1.2 yrs participated in 8-wk low-resistance strength training that involved static-dynamic knee and leg extension exercises 3–4 times/wk. The isometric MVC force and evoked twitch characteristics were examined before and after training. Isometric twitches of KE and PF muscles were evoked by percutaneous supramaximal electrical nerve stimulation. The MVC force of KE and PF muscles, and twitch rate of force development of PF muscles increased significantly with training. No significant changes in twitch peak force, postactivation potentiation, contraction and half-relaxation times, and rate of relaxation of KE and PF muscles has been found with training. The soleus H-reflex and M-wave peak-to-peak amplitude ratio remained unchanged with training. It was concluded that 8-wk low-resistance strength training increased maximal voluntary isometric strength of the leg extensor muscles without marked changes in evoked twitch contractile characteristics of muscles and spinal motoneuron pool excitability. The training-induced increase in voluntary muscle force-generating capacity with low-resistance static-dynamic exercises may comprise supramaximal adaptation mechanisms.

Key words: low-resistance strength training, contractile properties, knee extensor and plantarflexor muscles, skiers

INTRODUCTION

In endurance events, several factors have been demonstrated to be correlated with performance. Muscle strength and power is recognized as important components of successful performance in endurance sports [14], including cross-country skiing [21]. A specific type of strength training may lead to specific neural and muscular adaptations, such as the increased rate of activation of motor units, whereas muscle hypertrophy remains much smaller than during typical heavy-resistance strength training [22]. It is well known that contractile and oxydative properties of the slow-twitch muscle fibres play an important role in the improvement of aerobic and anaerobic threshold's speed as a basis of aerobic endurance. Force-generating capacity of slow-twitch muscle fibers can be developed by low-resistance static-dynamic and/or slow-speed strength exercises [2, 11, 15]. Low-resistance static-dynamic strength exercises have been performed in isotonic muscle regimen with slow speed and without muscle relaxation during 30–60 s [11]. In addition to strength development an improvement of aerobic and anaerobic threshold speed was attained by the low-resistance static-dynamic strength training. However, the peripheral and central mechanisms responsible for adaptation to low-resistance static-dynamic strength exercises are not fully known. We hypothesised that using low-resistance static-dynamic strength exercises it is possible to develop maximal voluntary strength of the leg muscles by contractile changes in slow-twitch muscle fibres and/or by neural adaptation. The yielded information helps to ground the methods of applying these exercises and create new possibilities for complex development of strength and endurance in endurance athletes when building the basis for aerobic performance.

The aim of the present study was to measure the effect of 8-wk low-resistance strength training program on voluntary and electrically evoked contractile properties of the knee extensor (KE) and plantarflexor (PF) muscles in young male cross-country skiers. More specifically, we recorded isometric maximal voluntary contraction (MVC) force and isometric twitch characteristics, and soleus maximal H-reflex and maximal motor response (M-wave) peak-to-peak amplitude ratio before and after the training program.

MATERIAL AND METHODS

Subjects

Nine young male cross-country skiers with mean age of 15.2±1.2 yrs, height of 173.1±7.4 cm and body mass of 61.8±7.0 kg volunteered to participate in this study. All subjects had trained at least 4 years for cross-country skiing. The experimental training period lasted for 8 weeks and was carried out after the competition season, when the total training volume was relatively low (7.3±1.7 h and 5–6 times/wk). Training involved static-dynamic strength exercises for leg extensor muscles. During the first 4 weeks subjects trained for 3 times/wk, and during the 5^{th}–8^{th} weeks 4 times/wk. Resistance training sessions consisted of knee and leg extension (squats, toe rises) and upper body (back extensions, press-ups) exercises with extra loads of 10–16 kg. In each exercise, 3–4 sets with 45–60 s of duration were performed. The MVC force and electrically evoked twitch contractile characteristics were examined before and after training. Informed written consent to participate was obtained. During the last 14 days before the study, the subjects were familiarized with the experimental setup. The study was approved by the University Ethics Committee for Human Studies.

Apparatus and measurements

The subjects were tested before and after 8-wk low-resistance strength training period by using identical protocols. All measurements were carried out on the dominant leg. The determination of the subject's dominant leg was based on a kicking preference. On reporting to the laboratory, the subject sat resting for ~ 30 min before experiment for minimizing any potentiation effect from walking to the laboratory.

During the testing of KE muscles the subject was seated in a custom-made dynamometer with the knee and hip angles equal to 90° and 110°, respectively [19]. The body position of the subject was secured by Velcro belts placed over the chest, hip and thigh. The unilateral knee extension isometric force of the dominant leg was recorded by standard strain-gauge transducer mounted inside a metal frame which was placed around the distal part of the ankle above the malleoli using a Velcro belt. The electrical signals from the strain-gauge transducer were digitized on-line (sampling frequency 1 kHz) using a personal computer. The digitized signals were stored on a hard disk for further analysis.

During the testing of the isometric MVC force of KE muscles the subject was asked to exit maximum voluntary isometric knee extension against the belt of the strain-gauge transducer as forcefully as possible for 2–3 s. Verbal encouragement and visual feedback were used to motivate the subjects. Three maximal attempts were recorded and the best result was taken for further analysis. A rest of 2 min was allowed between each of the three attempts.

To assess the contractile properties of KE muscles (quadriceps femoris), electrically evoked twitch was elicited by percutaneous electrical nerve stimulation. Prior to attaching the stimulating electrodes, electrode gel was applied to the contact surface, and the underlying skin was prepared by shaving, sanding and rubbing with isopropyl alcohol. Two carbon-impregnated rubber-stimulating electrodes were used — the cathode (4x4 cm) was placed on the skin over the femoral nerve in the inguinal crease and the anode (4x10 cm) was placed over the mid-portion of the thigh. The electrical stimuli were rectangular pulses of 1-ms duration applied at supramaximal intensity (130–150 V) delivered from an isolated voltage stimulator

(Medicor MG-440, Hungary). To determine the supramaximal stimulation intensity, the voltage of rectangular electrical pulse was progressively increased to obtain a plateau in the twitch force, i.e. when twitch force failed to increase despite additional increases in stimulation intensity. A stimulation intensity of 20–30% greater than that needed for maximal twitch response was used for further twitch measurements. After the resting twitch had been recorded, the subject was instructed to make a MVC for 5-s and then to relax. A second (potentiated) twitch took place within 2 s after the onset of relaxation. The following parameters were obtained from the averaged mechanical response of the three resting twitches: peak force (PT, the highest value of isometric force production); contraction time (CT, the time to peak force); half-relaxation time (HRT, the time of half of the decline in peak force); maximal rate of force development (RFD, the first derivate of the development of force, +dF/dt) and maximal rate of relaxation (RR, the first derivate of the decline of force, –dF/dt). The percentage increase in the potentiated twitch PF in relation to resting one was taken as indicator of the post-activation potentiation (PAP).

During the testing of PF muscles the subject was seated in a custom-made dynamometer chair with dominant leg flexed to 90° at the knee angle and mounted inside a metal frame [20]. The foot was strapped to an aluminium footplate. The inclination of the foot could be altered by rotating the footplate about on axis that corresponded to that of the ankle joint. The axis of rotation approximately alignated with the tip of the medial malleolus and the ankle was dorsiflexed to 20°. The kneecap and front side of the thigh were held down by an adjustable pad. Torques acting on the footplate were sensed by strain-gauge transducer connected with the footplate by rigid bar. Signals from the strain-gauge transducer were linear from 10–1600 N. The point of application of the force to footplate located on articulation regions between *metatarsus* and *ossa digitorum pedis*. The force signals were sampled at a frequency of 1 KHz and digitized signals were stored on a hard disk.

During the testing of the isometric MVC force of PF muscles the subject was instructed to push the footplate as forcefully as possible for 2–3 s. Verbal encouragement and visual feedback were used to motivate the subjects. Three maximal attempts were recorded and the best result was taken for further analysis. A rest of 2 min was allowed between each of the three attempts.

Twitch contraction of PF muscles (triceps surae) and soleus H-reflex and M-wave were evoked by percutaneous electrical nerve stimulation. Prior to attaching the stimulating electrodes, electrode gel was applied to the contact surface, and the underlying skin was prepared by shaving, sanding and rubbing with isopropyl alcohol. Two carbon-impregnated rubber-stimulating electrodes were used — the cathode (4x4 cm) was placed on the skin over the tibial nerve in popliteal fossa and the anode (4x10 cm) was placed under the posterior-medial side of the thigh. The electrical stimuli were rectangular pulses of 1-ms duration applied at supramaximal intensity (130–150 V) delivered from an isolated voltage stimulator (Medicor MG-440, Hungary). To determine the supramaximal stimulation intensity, the voltage of rectangular electrical pulse was progressively increased to obtain a plateau in the twitch force. A stimulation intensity 20–30% greater than that needed for maximal twitch response was used for further twitch contraction measurements. After the resting twitch has been recorded, the subject was instructed to make a MVC for 5-s and then to relax. A second (potentiated) twitch took place within 2 s after the onset of relaxation. The following parameters were obtained from the averaged mechanical response of the three resting twitches: PT, CT, HRT, RFD and RR. PAP was also calculated as mentioned above.

The H-reflex and M-wave of the soleus muscle was recorded using bipolar (20 mm interelectrode distance) electromyogram (EMG) electrodes (Beckman miniature skin electrodes). EMG recording electrodes were placed along the mid-dorsal line of the leg, about 5 cm distal from where two heads of gastrocnemius join the Achillis tendon. As a reference electrode a carbon rubber plate (4x10 cm) was placed over the proximal part of the triceps surae muscle between the stimulating and recording electrodes. The EMG signals were amplified and displayed using a standard preamplifier (Medicor MG-440, Hungary) with the frequency band ranging from 1 Hz to 1 kHz. These signals were sampled at 1 kHz.

During recording the the soleus H-reflex and M-wave indirect electrical stimulation intensity was progressively increased at 20-s intervals until maximal H-reflex was obtained. The maximal H-reflex was reached when an increase in stimulation intensity led to an increase in amplitude of the small M-wave, and decrease in the amplitude of H-reflex. The stimulation was continued until the H-reflex was abolished completely and the M-wave amplitude reached a plateau. The H- and M-waves were characterized by their peak-to-peak amplitude and the excitability of the motoneuron pool was assessed by computing the H:M ratio. Averaged amplitude of 5 maximal H-reflexes and M-waves evoked with interstimulating rest period of 10 s were analyzed.

Statistics

Data are means and standard deviations (±SD). One-way analysis of variance (ANOVA) followed by Scheffe *post hoc* comparisons were used to test for differences between pre- and posttraining values. A level of $p<0.05$ was selected to indicate statistical significance.

RESULTS

The isometric MVC force of KE and PF muscles in young skiers was significantly increased ($p<0.05$) with low-resistance strength training (Figure 1). No significant differences ($p>0.05$) in isometric twitch PT and PAP of KE and PF muscles were found after training as compared to pretraining level. The CT and HRT of KE and PF remained unchanged ($p>0.05$) with training (Figure 2). The twitch RFD of PF muscles was significantly increased ($p<0.05$) with training (Figure 3). There were no significant changes ($p>0.05$) in isometric twitch RFD of KE muscles, and RR of KE and PF muscles with training. The H/M ratio of the soleus muscle did not change significantly ($p>0.05$) with low-resistance strength training.

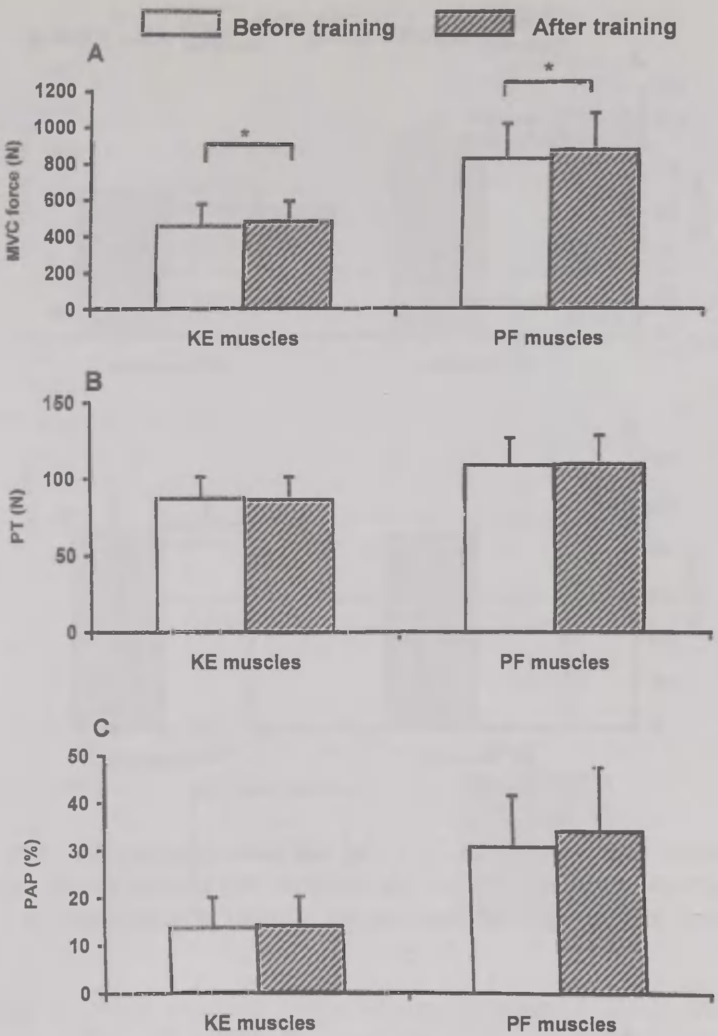

Figure 1. Maximal voluntary isometric contraction (MVC) force (A), isometric twitch peak force (PT) (B) and post-activation potentiation (PAP) (C) of the knee extensor (KE) and plantarflexor (PF) muscles before and after the 8-wk low-resistance strength training in young skiers (mean±SD). * significantly different compared with pretraining value.

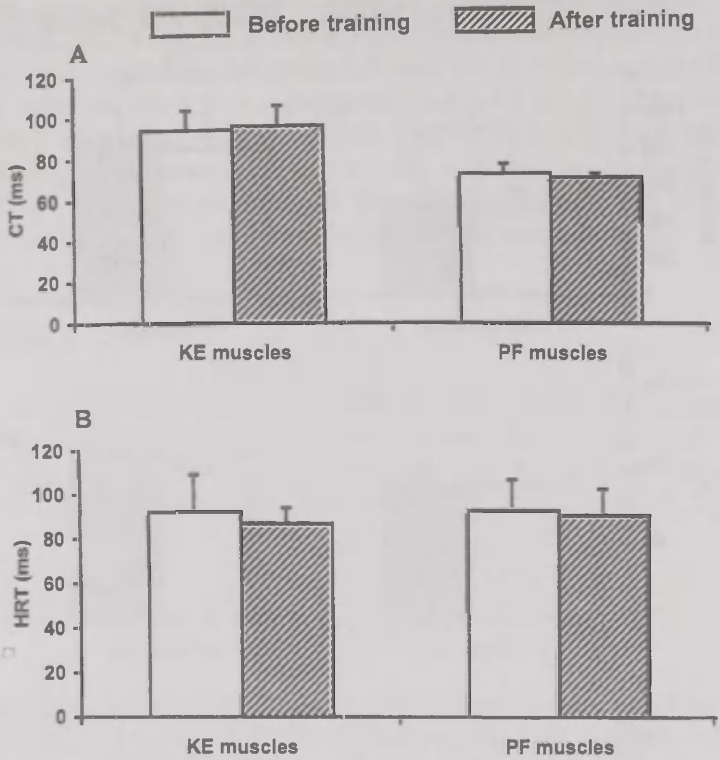

Figure 2. Twitch contraction (CT) (**A**) and half-relaxation (HRT) (**B**) times of the knee extensor (KE) and plantarflexor (PF) muscles before and after the 8-wk low-resistance strength training in young skiers (mean±SD).

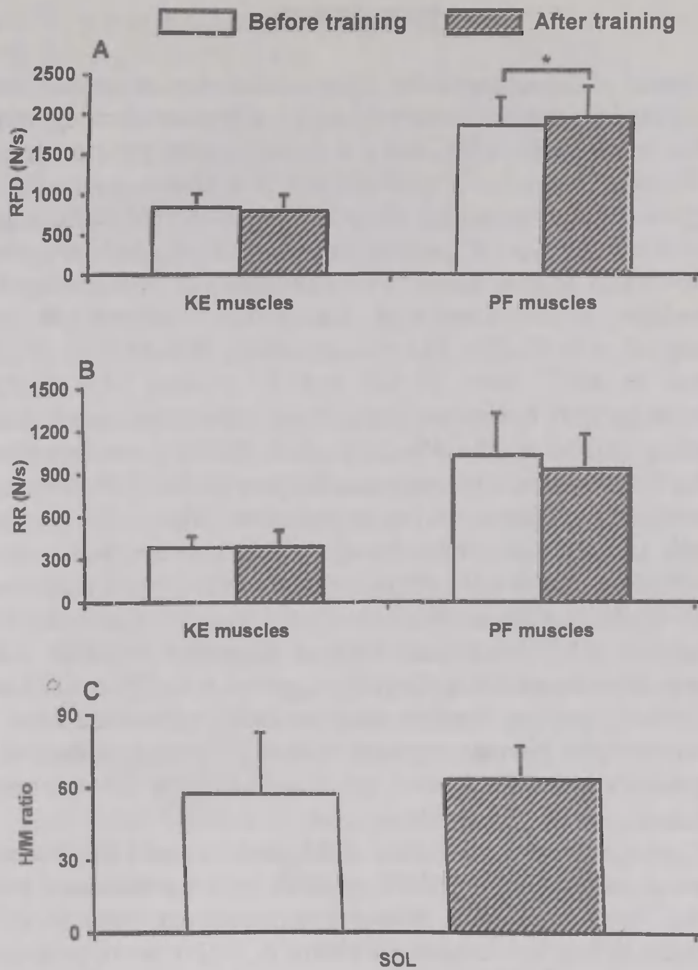

Figure 3. Twitch maximal rates of force development (RFD) (**A**) and relaxation (RR) (**B**) of the knee extensor (KE) and plantarflexor (PF) muscles, and soleus (SOL) H-reflex and M-wave peak-to-peak amplitude ratio (H/M) (**C**) before and after the 8-wk low-resistance strength training in young skiers (mean±SD). * significantly different compared with pretraining value.

DISCUSSION

The present study evaluated the effect of 8-wk low-resistance strength training which involved static-dynamic exercises for leg extensor muscles on isometric MVC force and twitch contractile properties of the KE and PF muscles in young skiers. It is known that during low-resistance strength exercises mostly the slow-twitch motor units are recruited and this type of training program influences adaptive changes in slow-twitch muscle fibers. These changes can be considered as a precondition to an increase of mitochondrial volume and aerobic capacity of muscle [7]. The present study demonstrated a marked increase in MVC force of KE and PF muscles (4.8 and 5.6%, respectively) with 8-wk low-resistance static-dynamic strength training in young skiers. A 15–34% increase in MVC force in endurance athletes was reported after resistance training [4, 5, 10]. However, these observations are based on experiments in which heavy-resistance strength training has predominated, which increase force-generating capacity slow- and fast-twitch muscle fibers and can lead to decrease in the oxidative capacity of muscles. Albertti et al. [2] observed a 8–16% increase in MVC force with 8-wk of superslow-resistance strength training. Mjakintshenko et al. [11] suggested a significant increase in MVC force, and in aerobic and anaerobic thresholds after low-resistance static-dynamic strength training. They hypothesised that using that kind of training method no conflict occurs between muscle's endurance and resistance abilities.

In present study the soleus H/M peak-to-peak amplitude ratio increased unsignificantly (10,3%, $p>0,05$) with low-resistance strength training. Previous studies indicated a significant increase in H/M amplitude ratio with endurance training [9, 16] and hopping training [25]. However, Aagaard et al. [1] did not observe a significant change in H/M amplitude ratio with resistance training. The maximal H-reflex is elicited by submaximal nerve stimulation and is mainly due to the activation of the slow-twitch motor units [12]. The maximal M-wave is elicited by supramaximal nerve stimulation and is the electrical counterpart of the activation of all motor units of the pool, including the fast-twitch units. The H/M ratio may be useful to assess motoneuron pool excitability [6, 12]. This study did not demonstrate a significant change in soleus motoneuron pool excitability with low-resistance strength training in young skiers.

The present study indicated no significant changes in twitch PAP with low-resistance strength training in KE and PF muscles. PAP of PF muscles in young skiers (31 and 34,3% before and after training, respectively) was less than that published previously for age-matched boys (42%) [20]. It has been shown that subjects with a greater percentage of fast-twitch fibers, and shorter CT and HRT time tended to have greater PAP [13, 24]. PAP in PF muscles is greater in power-trained than endurance-trained and untrained subjects, whereas no significant difference exist between endurance-trained and untrained subjects [17].

It has been shown that twitch force-generating capacity does not differ in endurance-trained male athletes as compared to untrained subjects [18]. The present study also demonstrated that twitch PT of PF muscles not differ significantly in young (15-year-old) male skiers from data that published previously for age-matched untrained boys, whereas CT and HRT in skiers were shorter [20]. The 8-wk low-resistance strength training did not result in significant changes in isometric twitch PT, CT, HRT and RR of KE and PF muscles in young skiers. Only twitch RFD of PF muscles was significantly increased with training. Thus, the measured 8-wk low-resistance strength training induced only little changes in electrically evoked twitch contractile properties of leg extensor muscles. This is in agreement with Maffiuletti and Martin [8] who observed no significant changes in evoked twitch contractile properties with progressive isometric resistance training. It has been suggested that during relatively short training periods of some weeks, the increase in force-generating capacity of muscles, especially in endurance athletes, might primarily be caused by neural adaptation without observable muscle hypertrophy [3]. The present training-induced increase in MVC force also migh primarily be due to neural adaptations, although the loads used in the present strength training were low.

In conclusion, the present study demonstrated that 8-wk low-resistance static-dynamic strength training in young cross-country skiers is characterized by increase in maximal voluntary isometric strength of the leg extensor muscles without marked changes in isometric twitch contractile characteristcs and spinal motoneuron pool excitability. The training-induced increase in voluntary muscle force-generating capacity with low-resistance strength training can be explained by supraspinal adaptation mechanisms, i.e. increased central motor drive. Finally, it should be remembered that the used strength training program was a moderate one, and it seems likely that training at higher intensity and/or longer duration is required for more significant changes in neuromuscular function.

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THE EFFECT OF CYCLING OF DIFFERENT INTENSITY ON THE RED AND WHITE BLOOD PARAMETERS

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ABSTRACT

Physical loads of various intensity exert a specific influence on the organism, which should also be expressed in the post-load changes of the blood parameters. The aim of the present study was to find out the effect of the sport-specific load of different intensity on the blood parameters in cyclists and determine the speed of the recovery of the changes. The subjects of the study were 15 cyclists aged 16–25 years (17.9±3.1). First, for the development of general endurance, subjects cycled at a uniform speed for 3.5 hours in the heart rate zone of general endurance with an intensity of 55–65% of VO_2max. Second, for the development of speed endurance the subjects covered 25 km at a maximum speed with an intensity of 85–95% of VO_2max. Under the influence of the less intensive general endurance training load the subjects' amount of Hgb, Hct and E increased immediately after physical strain. Maximum changes of the white blood immediately after loading and almost complete recovery took place during 18 hours after physical strain. Under the influence of a more intensive speed endurance training load the subjects' amount of Hgb, Hct and E decreased immediately after physical strain. The most significant changes in the parameters of the white blood were not detected immediately after speed endurance training but 2 hours after physical strain, while not all white blood indices were completely restored 18 hours after loading.

Key words: red blood, white blood, general endurance, speed endurance, cyclists

INTRODUCTION

Development of general and speed endurance in endurance sport athletes depends on training loads of different intensity. In development of general endurance, physical load of lower intensity and aerobic capacity is one of the major components of development since aerobic energy supply enables to perform strenuous exercise for a longer period. In order to ensure the required level of energy production, respiratory and circulation systems and different blood components participate in transporting oxygen from the outer air to a working muscle. Development of speed endurance involves training loads of higher intensity. In this case an important component of development is anaerobic energy supply, which means that anaerobic energy production will play a more important role alongside the aerobic mechanism of energy supply. The by-products of anaerobic metabolism (lactate) increase the acidity of the tissues and blood, and the organism develops metabolic acidosis [6, 9, 10, 13]. Physical loads of various intensity exert a specific influence on the organism, which should also be expressed in the post-load changes of the blood parameters.

The aim of the present study was to find out the effect of the sport-specific load of different intensity on the blood parameters in cyclists and determine the speed of the recovery of the changes and the factors influencing it.

MATERIALS AND METHODS

The subjects of the study were 15 cyclists aged 16–25 years (17.9±3.14). In laboratory conditions their morphological and respiratory indices such as body mass, body height, body fat percentage, body fat mass, lung capacity, forced respiratory capacity in seconds and maximum ventilation were determined. Body fat mass was measured using Omron BF 300 Body Fat Analyzer (Omron, Japan) and the respiratory indices were measured with the Flow Screen Pro apparatus (Erich Jaeger, Germany). Functional fitness (maximum aerobic capacity, aerobic threshold and anaerobic threshold, spurt strength, physical working capacity and recovery speed) were determined using a test cycle ergometer (Monark 818E, Sweden), oxygen consumption was determined using Metamax-2 (Cortex, Germany). Stepwise increasing loads with a spurt at the end of the last load were applied. The cycling training of different intensity was used in order to study the sport-specific physical load. First, for the development of general endurance, subjects cycled at a uniform speed for 3.5 hours in the heart rate zone of general endurance with an intensity of 55–65% of maximum oxygen consumption. Second, for the development of speed endurance the subjects covered 25 km at a maximum speed in the heart rate zone with an intensity of 85–95% of maximum oxygen consumption. Venous blood for analyses was sampled at rest (1 hour before the training), immediately after the training and at 2 and 18 hours of the recovery period after the training. Clinical analysis of the blood was performed using a blood analyser "Sysmex 2000" (Japan). Haemoglobin (Hgb), hematocrit (Hct), erythrocytes number (E) as well as the erythrocyte indices [mean cell volume (MCV), mean cell haemoglobin (MCH), mean cell haemoglobin concentration (MCHC), red cell distribution width, coefficient of variation (RDW-CV)], leukocyte number (L) and the leukocyte formula were determined.

For assessment of the organism's adaptation to the physical load and for studying the specificity of the recovery, heart rate monitoring was carried out both during the test cycling and during 18 hours of the recovery. Heart rate monitors Polar Accurex Plus and Polar XTrainer Plus (Polar Electro Oy, Finland) were used for heart rate (HR) monitoring and the obtained data were processed with the Precision

Performance Software (Polar Electro Oy, Finland). Training zones were determined on the basis of the heart rate data (HR at rest, HR at aerobic threshold, HR at anaerobic threshold and maximum HR). The heart rate recording interval was 5 seconds during the test cycling and 60 seconds during the recovery period.

Statistical analysis of the results was performed using software “Statistic”. Mean values and standard deviations for normally distributed data were calculated using descriptive statistics. Differences between the study groups were analyzed by unpaired Student’s t-test. Linear correlation coeffcients were used to describe relationships between the variables, while $p<0.05$ was considered statistically significant.

RESULTS

The functional and morphological indices of the subjects are presented in Table 1.

The athletes' indices showed a great individual variety of body mass and height; body fat percentage and body fat mass were within norm, and the functional indices of respiratory system exceeded the age dependent theoretical norm.

The functional indices of physical fitness determined on the basis of a laboratory veloergometric test characterised the athletes as possessing high aerobic capacity, high aerobic and anaerobic threshold, high spurting capacity and fast recovery.

The blood parameters of the cyclists during both the general and the speed endurance training are presented in Tables 2 and 3

Table 1. Morphological and functional parameters of the subjects of the study.

No	Parameter	Mean	Minimum	Maximum	SD
1.	Body height (cm)	180.5	164.0	192.0	7.9
2.	Body mass (kg)	66.5	46.0	90.0	9.4
3.	Body fat percentage (%)	9.35	4.0	16.3	3.8
4.	Body fat mass (kg)	6.32	2.0	11.4	3.0
5.	Lung capacity (l)	5.54	4.0	7.8	1.2
	Theoretical norm (%)	110.1	94.0	131.0	11.8
6.	Forced respiratory capacity in seconds (l/sek)	4.8	3.4	5.9	1.1
	Theoretical norm (%)	110.2	100.0	124.0	10.3
7.	Maximum ventilation (l/min)	171.2	112.0	214.0	44.2
	Theoretical norm (%)	119.7	95.0	154.0	20.4
8.	Maximum aerobic capacity (ml/min/kg)	67.4	60.0	77.6	5.6
9.	Aerobic threshold (l/min)	147.7	135.0	160.0	7.7
10.	Anaerobic threshold (l/min)	176.8	165.0	184.0	6.3
11.	Physical working capacity (W/kg)	3.96	3.4	4.7	0.5
12.	Spurt (revolutions per minute)	129.8	116.0	139.0	9.1
13.	Spurt strength (W/kg)	6.74	5.8	7.4	0.6

Table 2. Changes in the subjects' red blood parameters under endurance training of different intensity load (M±SD).

		Parameters	1 hour before the training	Immediately after the training	2 hours after the end of the training	18 hours after the end of the training
Endurance	General	Haemoglobin (g/l)	141.2±4.91	143.2±6.22	139.4±5.17	139.2±7.71
		Hematocrit (%)	41.9±1.5	42.2±1.92	41.1±1.95	40.9±1.55
		Erythrocytes ($x10^{12}/l$)	4.71±0.304	4.79±0.225	4.66±0.275	4.62±0.274
		MCHC (g/l)	337.2±4.39	339.1±4.52	339.1±7.13	339.7±6.00
		MCH (pg)	30.0±1.59	29.9±1.47	29.9±1.48	30.1±1.31
		MCHC (g/l)	337.2±4.39	339.1±4.52	339.1±7.13	339.7±6.00
		RDW-CV (%)	12.5±0.58	12.5±0.60	12.6±0.60	12.8±0.64
	Speed	Haemoglobin (g/l)	148.5±8.07	146.9±8.44	142.6±9.84	145.5±7.28
		Hematocrit (%)	43.7±2.32	43.1±2.04	41.6±2.51	42.4±2.09
		Erythrocytes ($x10^{12}/l$)	4.98±0.27	4.93±0.22	4.79±0.28	4.82±0.26
		MCHC (g/l)	340.2±7.8	340.9±8.3	342.5±7.3	343.3±7.0
		MCH (pg)	29.8±1.68	29.8±1.78	30.4±3.73	30.3±1.65
		MCHC (g/l)	340.2±7.8	340.9±8.3	342.5±7.3	343.3±7.0
		RDW-CV (%)	12.7±0.63	12.6±0.64	12.6±0.63	12.8±0.68

Table 3. Changes in the subjects' white blood parameters under endurance training of different intensity load (M±SD).

	Parameters	1 hour before the training	Immediately after the training	2 hours after the end of the training	18 hours after the end of the training
Endurance General	Leukocytes ($x10^9/l$)	4.81±0.95	13.12±6.76	12.15±4.08	5.21±1.18
	Neutrophils ($x10^9/l$)	2.34±0.76	10.43±7.17	9.74±5.0	3.04±1.58
	Neutrophils (%)	48.6±11.1	79.5±6.34	80.2±6.8	58.3±13.7
	Lymphocytes ($x10^9/l$)	2.0±0.39	1.9±0.44	1.8±0.56	1.7±0.49
	Lymphocytes (%)	41.6±12.4	14.5±6.22	14.8±6.76	32.6±12.3
	Monocytes ($x10^9/l$)	0.36±0.16	0.68±0.55	0.56±0.17	0.39±0.19
	Monocytes (%)	7.5±2.93	5.2±2.54	4.6±2.83	7.5±3.02
	Eosinophils ($x10^9/l$)	0.10±0.05	0.08±0.06	0.03±0.043	0.07±0.046
	Eosinophils (%)	2.1±2.65	0.6±2.65	0.2±2.45	1.3±2.04
Speed	Leukocytes ($x10^9/l$)	5.42±1.35	7.19±1.71	10.02±2.97	5.86±1.2
	Neutrophils ($x10^9/l$)	3.0±0.98	4.3±1.24	7.42±2.98	2.91±0.81
	Neutrophils (%)	55.4±10.7	59.8±8.1	73.8±11.0	49.5±8.3
	Lymphocytes ($x10^9/l$)	1.61±0.34	2.22±0.44	1.78±0.52	2.19±0.79
	Lymphocytes (%)	29.5±7.9	30.5±6.1	17.9±8.8	37.5±11.4
	Monocytes ($x10^9/l$)	0.47±0.06	0.48±0.05	0.70±0.29	0.52±0.26
	Monocytes (%)	8.7±2.93	6.7±2.17	6.9±2.98	8.8±4.13
	Eosinophils ($x10^9/l$)	0.28±0.21	0.18±0.09	0.10±0.08	0.21±0.17
	Eosinophils (%)	5.3±4.27	2.5±1.22	1.1±0.89	3.6±3.2

DISCUSSION

The subjects of the study displayed a high level of aerobic capacity: VO_2max (67.4±5.67 ml/min/kg), HR at aerobic threshold (147.7±7.7 bpm) and HR at anaerobic threshold (176.5±6.3 bpm) and spurt strength (458.0±53.1 W) are comparable with the respective parameters of top cyclists [15, 21]. The high values of the subjects' respiratory indices indicate a great reserve of respiratory function for ensuring high aerobic work capacity.

The average HR of the subjects measured during the general endurance training was 150.1±11.1 bpm. The training proceeded at a uniform speed, the fluctuations in HR were related to the track profile and to the greater exertion in the lead of the group. This particular training load was directed to the development of general endurance, which is confirmed by the large proportion (87.8%) of the time spent in the HR zone of general endurance. At the beginning of the recovery period, immediately after the training, HR was 143.9±18.5 bpm after which it started to decrease: at 2 hours after the training it was 91.5±16.6 bpm and at 18 hours after exercise it had practically returned to the pre-training level (53.6±6.4 bpm).

The indices of HR during the other sport-specific test (25 km of cycling at maximum speed) confirm that training load had been aimed at the development of speed endurance of the subjects, as energy production during the test training was of anaerobic kind. The average HR of the subjects measured during the speed endurance training was 176.0±6.46 bpm, while the maximum HR was 189.7±8.89 bpm and the minimum was 164.9±6.51 bpm. Changes in HR during recovery were unidirectional, however, the process proceeded at a different speed. Immediately after the training, HR values were high (183.3±7.54 bpm). The rate of recovery tempo was first high and 2 hours after the training HR was essentially restored (90.8±13.87 bpm); thereafter recovery rate slowed down and reached the pre-loading level of the average indices (56.4±13.69 bpm) 18 hours after the loading.

The main energy supply mechanism in endurance development is aerobic production, which is largely associated with oxygen transport and consumption. The results of the study demonstrate (Table 2) that changes in the average values of the red blood parameters (Hgb, Hct, E), ensuring oxygen transport in the post-load period, have a small range. An increase in the parameter values observed immediately after the training indicates the involvement of the erythrocytes of the blood depot in adaptation to the load. However, as early as 2 hours after the training the average indices of the red blood were below the pre-load level and the decrease continued (their recovery during 18 hours was significantly slower compared with the recovery of HR), the lowest values being observed on the following day. The studied erythrocyte indices (MCV, MCH, MCHC and RDW-CV) did not reveal a significant change in relation to the given load, either.

The training load directed at the development of speed endurance increases the intensity of oxygen transport and assimilation. Immediately after training a decrease in Hgb, Hct and E were observed. 2 hours after the training, the decrease in red blood parameters continued and after 18 hours of recovery it was notably slower than the restoration of heart rate. In some cyclists the speed endurance training led to the emergence of young erythrocytes (reticulocytes) in their blood in the post-load period.

Training process exerts a strong influence on a top athlete's organism causing sport-specific changes. Training process also has a specific effect on the blood components, which allows to estimate the training load and its influence on the organism [16, 19, 20]. Haematological studies in athletes at rest have revealed no differences in the blood parameters between athletes and non-athletes or between representatives of different fields of sport; the blood parameters of athletes have been shown to be within norm [1, 13]. Also, it has been found that endurance athletes have significantly higher haemoglobin content and a larger blood volume [14]. More attention has been paid to the investigation of haemoglobin content and erythrocyte number, since there is a real danger, particularly in female athletes [5], of developing sport anaemia. Sport anaemia is induced by the strain haemolysis of the blood and erythrocyte impairment under the influence of the physical load, characterised by an increase in erythrocyte size and the growth of reticulocyte number and a decrease in haptoglobin level [5, 22]. Important causes are also iron deficit caused by under nourishment, vegetarianism, carbohydrate rich diet, low iron content in food, a large share of special food items (sports powders, mixed food, chocolates, etc) in athletes' food ration, as well as indigestion disorder and loss in weight [5]. Under physical loading the share of young erythrocytes increases, their higher capacity for deformation and lower affinity to oxygen increase the potential of supplying the muscles with oxygen. In order to avoid the diagnosis of pseudoanaemia, it is essential to estimate Hct, Hgb and E as well as to take into account the increase in the volume of blood plasma in athletes [10, 14]. As Hgb and E determine the aerobic capacity of the organism, both allowed alpine environment (high altitudes, alpine cottage) and, regrettably, also non-allowed (blood doping, erythropoietin) means are used [3, 4, 12, 17].

Muscle work increases the number of leukocytes in the blood. In our study changes in the average values of white blood parameters in the post-load period of the general endurance training (Table 3) showed definite dynamics and had a large range. Immediately after the training the leukocyte number increased ($p<0.001$), which occurred at the expense of an increase both in the absolute ($p<0.01$) and relative ($p<0.05$) number of neutrophils. At the same time, a decrease ($p<0.05$) was noted in the number of lymphocytes and monocytes. Thus, established leukocytosis and changes in the proportions of the white blood cells persisted for 2 hours after loading. Complete recovery of the parameters of the white blood cells occurred during 18 hours.

In this study, changes in the average values of the white blood parameters in the post-load period of the speed endurance training showed a definite dynamics and had a large range. Immediately after the training leukocyte number increased and the increase continued for 2 hours after the loading (before the training: 5.42±1.35; immediately after the training: 7.19±1.71; 2 hours after the training: 10.02±2.97 $x10^9/l$). The increase in the leukocyte number was related to the increase both in the absolute and relative number of neutrophils. At the same time, a slight increase was noted in the absolute and a decrease in the relative number of lymphocytes and monocytes. Both the absolute number and the relative number of eosinophils and basophils decreased in the post-load period. Hence leukocytosis and changes in the proportions of the white blood cells, resulting from loading, progressed for 2 hours after physical loading and their recovery during 18 hours was not complete.

The less intensive general endurance training caused a maximum increase in leukocytes immediately after exercise and a nearly complete recovery 18 hours after physical strain. The increase occurred at the expense of the increase in the number of neutrophils, while the other white blood components displayed both an absolute and a relative decline [2, 7]. The intensive speed endurance training caused small-range changes in the white blood, which progressed during 2 hours after the end of loading, and the recovery of these parameters was not complete after 18 hours. According to literature, the number of leukocytes increases after physical training, and the increase depends on the degree of the athlete's fitness: the higher is the degree of fitness, the smaller is the increase in leukocytes [2, 8]. The increase in the number of leukocytes occurs at the expense of the increase in the number of neutrophils and lymphocytes [7, 11]. It has been found that the phagocyte activity of leukocytes in athletes at rest is reduced about 70% compared with untrained individuals [2]. The increase in both the absolute and the relative number of neutrophils under the influence of a submaximal physical load reflects the rise in phagocyte activity [2]. The change of phagocyte activity in different periods of training process may be associated with the production of cortisol and epinephrine in the organism [18]. As a rule, the number of lymphocytes increases immediately after intensive physical exercise, while the number of "killers" grows at a higher rate than the numbers of lymphocyte subpopulations. Further the number of leukocytes drops below pre-exercise level [7, 8]. Changes in the leukocyte number and proportions reflect the fluctuations in the immunological status of the athlete's organism under the influence of physical loading [2, 11].

On the basis of the present study it can be concluded that physical loads of different intensity cause respective changes in the red and white blood:

1. Under the influence of the less intensive general endurance training load the subjects' amount of haemoglobin and hematocrit and the number of erythrocytes increased immediately after physical strain. Under the influence of a more intensive speed endurance training load the amount of haemoglobin, hematocrit and the number of erythrocytes decreased immediately after physical strain.

2. The less intensive general endurance training load caused maximum changes of the white blood immediately after loading and almost complete recovery took place during 18 hours after physical strain. An intensive speed endurance training induced changes both in the number and proportions of the white blood components. The most significant changes in the parameters of the white blood were not detected immediately after speed endurance training but 2 hours after physical strain, while not all white blood indices were completely restored 18 hours after loading.

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SELF-REPORTED HEALTH, HEALTH STATUS AND FUNCTIONAL CAPACITY OF TRACK AND FIELD ATHLETES OF TARTU

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ABSTRACT

The aim of this investigation was to establish the relations between reported health, health status and functional capacity in track and field athletes of Tartu. The study included the following items: analysis of general appreciation of health by the junior athletes, analysis of the health status of junior athletes in medical checkup; analysis of functional abilities and the establishment of the relationship between health status and functional ability .

The subjects were 160 track and field athletes, aged 10–25 years which were divided into 2 groups according to age and length of participation in the sport: Group A (younger, 10–15yrs, trained 3–4 times per week for up to 2 years) and group B (16–25yrs, trained 5–7 times per week for more than 2 years).

The analysis revealed that among the track and field athletes of Tartu, 95.7% reported their health as "very healthy" and "healthy", but medical observation established high occurrence of health disorders (~52% average of all participants). In the younger age group 70.6% and in the older age group 60.5% of the subjects belonged to an excellent functional class. The dependence of distribution into functional classes on the frequency of occurrence of health disorders shows the expediency of applying the corresponding methods in estimating the functional abilities of athletes. Regardless of the existence of the relatively high frequency of health disorder occurrence (injury and other forms of medical problems) subjective health (self-reported health status) was rated as good or very good in the track and field athletes of Tartu.

Key words: athletes health, health disorders, injuries.

INTRODUCTION

The recommendation for physical activity to achieve and promote health and to prevent disease signals a shift in the exercise-fitness paradigm to emphasize the relationship between physical activity and health. A distinction is made between scheduled vigorous exercise and intermittent moderate physical activity [2,3,4].

To enhance long-term participation by people in regular physical activity and sport, several factors should be considered, especially those that pertain to the person (age, gender, health status, etc.) and exercise regimen itself. Studies show that health benefits are still achieved better by moderate-intensity than to vigorous-intensity physical activity programs. Doing strenuous exercise (>75% VO2 max) for more than 5 sessions per week increases the risk of orthopedic problems, cardiac complications [10] and potential problems (the female athlete triad) of excess exercise for women. In additional to overtraining, several other exercise-induced health risk factors have been identified [7]. Special precautions are needed for sport activity in young ages, in particular to skeletal, somatic and sexual maturation.

The aim of the present investigation was to establish the relations between reported health, health status and functional capacity in track and field athletes of Tartu.

MATERIALS AND METHODS

The subjects of the study were 160 track and field athletes of Tartu Track and Field School aged 10–25 year old. The participants divided into 2 groups (A and B) according to age and length of sporting (A group: younger, 10–15yr, who exercitsed 3–4 times per week for up to 2 years, and B group: older, 16–25yrs, who exercised 5–7 times per week for more than 2 years). The study was carried out by the Clinic of Sports Medicine and Rehabilitation, University of Tartu. The athletes were tested during the competition period of training in accordance with their regular medical checkup. This study was approved by the Medical Ethics Committee of the University of Tartu (Estonia). Written informed consent was given by each subject.

Height and body mass of the athletes were measured by Martin metal anthropometer (±0.1 cm) and medical scale (±0.05 kg), respectively. BMI (kg/m^2) was calculated.

Determination of the functional state of the subjects was carried out by means of the cycle ergometric test using the "Siemens Ricord 460" equipment. During the test the heart rate, the arterial blood pressure, the maximum load endurance, and the ECG were recorded. The heart rate (HR, beats/min) was taken by using the Sport-tester "Polar Electro PE 3000" in a state of rest (lying and sitting), during the load test, and upon recovery 15 minutes. At the end of each load, arterial blood pressure was taken auscultatively. The initial load on the cycle ergometer 50 W for women and 100 W for men. The load was gradually raised after every 3 minutes by 50 W and 75 W, respectively, maintaining the pedalling frequency of 70 revolutions per minute. The test was terminated upon reaching the maximum heart rate (age-predicted norm), reaching maximum blood pressure, appearance of changes in the ECG, or signs of essential fatigue.

Reported health: perceiving general health was elicited by asking the subjects describe their general health as “very good”, “good”, “not good” or “poor”. Perceived health incorporates a variety of physical, emotional, and personal components of health to comprise individual “healthiness”. As such, perceived health is a broad indicator of health related well-being [6].

The state of health of the subjects was estimated by personal medical histories of physical examination and determined from objective findings during the medical check up.

Standard statistical methods were used to calculate mean ($\overline{X}$) and standard deviation (±SD) . Statistical comparisons between groups were made using independent t-test. Statistical significance was set at $p<0.05$.

RESULTS

Anthropometric and functional capacity data of the subjects are presented in Tables 1 and 2. Track and field athletes of both groups (younger and older) display high characteristics of functional capacity: PWC_{170}, VO2 max. The significant difference was between younger and older groups in VC, PWC_{170}, VO2 max characteristics for the same sex ($p<0,05$).

The majority (~93%) of subjects considered themselves as ”healthy” or “very healthy” (Table 3).

The determination of the state of health by personal medical histories, by physical examination, and from objective findings during the medical check up, revealed health disorders ranging from slight functional disturbances to single serious diseases. The percentage of persons with health disorders among the subjects under study was considerably high (average at all contingent ~52%).

The health disorders among the subjects under study have had different nature (infection, somatic diseases, musculoskeletal injuries), and different genesis mechanisms (inappropriate exercise or overexertion), which could produce significant health risks. Distribution of health disorders among the subjects under study are represented in Figures 1–4.

Table 1. The anthropometric data of the subjects ($\overline{X} \pm SD$).

Characteristics	Younger group (A group)		Older group (B group)		
	Girls (n=40)	Boys (n=40)	Women (n=40)	Men (n=40)	p
Age (yr)	13.48±1.26	13.61±1.50	18.85±2.64	17.73±1.78	
Height (cm)	161.56±8.45	168.22±11.28	171.57± 8.34*	182.24±7.09*	< 0.05
Mass (kg)	47.94±8.08	54.91±13.52	63.28±10.60*	73.70±8.63*	< 0.05
BMI (kg/m^2)	18.27±1.99	18.79±2.81	20.91±2.29*	22.08±2.08*	< 0.05

*The significant difference was between A and B groups in the body height, mass, BMI characteristics for the same sex (p<0.05).

Table 2. Characteristics of functional capacity of the subjects ($\overline{X} \pm SD$)

Characte-ristics	Younger group (A group)		Older group (B group)		
	Girls (n=40)	Boys (n=40)	Women (n=40)	Men (n=40)	p
PWC_{170} (W)	113.23±32.07	157.98±38.4*	170.98±46.90	218.15±43.38*	<0.05
PWC/kg (kgm/min)	14.61±2.40	17.59±2.83*	16.59± 3.25	20.05± 3.11*	<0.05
VO2 max (l/min)	2.53±0.40	3.14± 0.59*	3.28± 0.67	4.17± 0.49*	<0.05
VO2 (ml/min/kg)	53.70±7.06	58.45±8.42*	54.43± 8.04	57.70± 7.37*	<0.05
Recovery HR for 3 minutes (total)	337.13±40.54	330.10±37.55	326.68±45.00	327.00±42.16	<0.05
Load endu-rance (W/kg)	2.41±0.39	2.95±0.44	3.19± 2.98	3.16± 0.43	>0.05

* The significant difference was between A and B groups in PWC_{170}, VO2 max characteristics for the same sex (p<0.05).

Table 3. Distribution (%) of self-reported general health of athletes (n=160)

Perceived general health	Girls,%			Boys,%		
	A Younger group (n=40)	B Older group (n=40)	Total	A Younger group (n=40)	B Older group (n=40)	Total
"Very good"	52.4%	46.0%	49.2%	64.2%	53.4%	58.8%
"Good"	43.6%	47.0%	45.3%	43.8%	42.6%	43.2%
"Not good"	4.0%	7.0%	5.5%	2.0%	4.0%	3.0%
"Poor"	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

The health state determination in accordance with the medical check-up revealed that the nature and quantity of health disorders among the younger and older subjects under study differed: the older athletes group showed more problems with musculoskeletal and cardiorespiratory system.

Despite the fact that percentage of persons with health disorders among subjects under study was comparatively large, the functional capacity characteristics in the "practically healthy" group and the "health disorders" athlete group were high (Table 4).

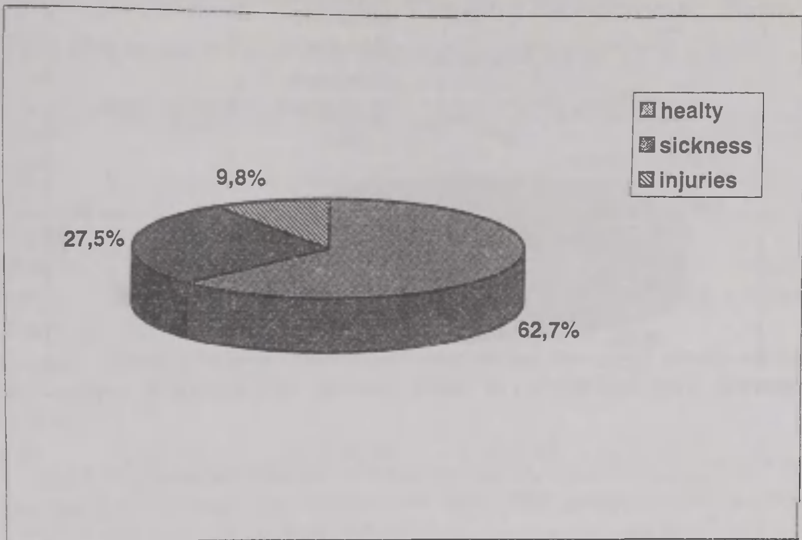

Figure 1. Distributions (%) of health disorders in A groups of girls.

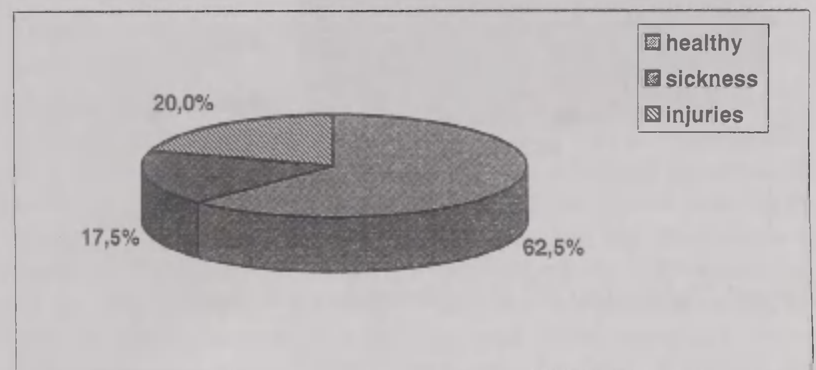

Figure 2. Distributions (%) of health disorders in A groups of boys.

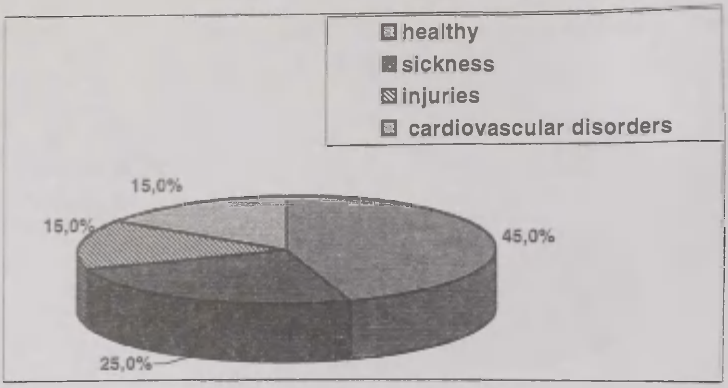

Figure 3. Distributions (%) of health disorders in B groups of women.

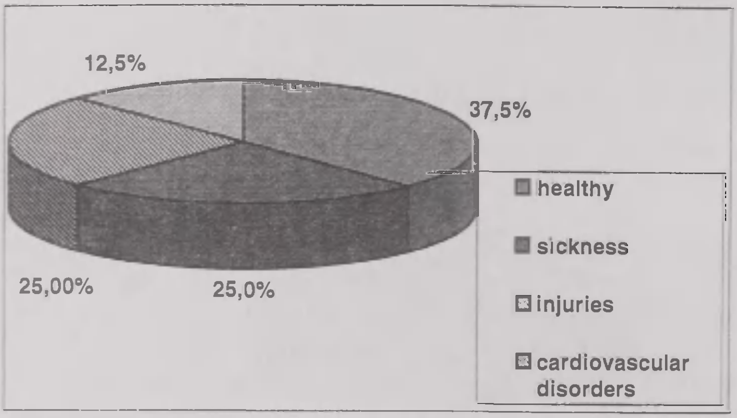

Figure 4. Distributions (%) of health disorders in B groups of men.

Table 4. Characteristic of functional capacity for "practically healthy" ("PH") athletes and athletes with "health disorders"("HD"). ($\overline{X} \pm SD$)

	Younger group A		Older group B		
Charac-teristic	"PH"*	"HD"	"PH"	"HD"	p
N	n=50	n=30	N=45	n=35	<0.05
VO2 max (l/min)	2.94±0.62	2.75±0.61*	3.83±0.82	3.77±0.71*	<0.05
PWC_{170} (W/kg)	3.00±0.34	2.45±0.44*	3.01±0.53	2.93±0.43	<0.05
Recovery HR for 3 minute	335.63±39.22	332.84±37.17	330.89±45.99	325.97±39.56	<0.05
BMI	18.40±2.13	18.27±2.69	21.10±2.09	21.87±2.39	<0.05

*The significant difference was between *"PH"* and *"HD"* groups in PWC_{170}, VO2 max characteristics for the same sex ($p<0.05$).

DISCUSSION

Numerous studies over the past several decades have demonstrated the significant positive effects that physical exercise can have on health. The cardiac, pulmonary and endocrine benefits of sports participation have been extensively documented. The sports can have a profoundly beneficial effect on participants in both the physical and psychological realms. On the other hand, there are well-recognized risks associated with sports participation. Recently, it has been recognized that serious cardiovascular consequences may also result from aggressive sports participation, and these consequences may be fatal. Although the incidence of diseases among sporting persons is considerably lower than among untrained persons, the occurrence of health disorders in competitive sports is due to extreme physical and psychological strain. Cases of death owing to acute cardiopulmonary inadequacy in competitive conditions have been reported [8, 9, 11].

The present study has provided results (high incidence of health disorders, unfavorable cardiovascular reactions, etc.), which should be considered in the course of medical monitoring as well as in making training plans. Thus, the frequency of sport injuries among subjects of this study was relatively high, and especially so among male B group athletes (25%). Sports injuries are prevalent enough that a whole field of sports medicine has grown up around their prevention, recognition and treatment. In general, the musculo-skeletal system is at particular risk for injury in the course of most sport activities. Injuries of the supportive-locomotive apparatus are quite common among persons practising both sport and physical culture and their numbers have grown with the growing numbers of athletes [3]. The most common type of injures recognized by subjects under study were: torn and pulled tendons and ligaments, muscle strain and pain, broken bones.

The occurrence of unfavorable reactions of the cardiovascular system among this group of athletes during graded cycle ergometric testing deserves attention. Systematic physical loads cause functional changes in the state of organ systems which, owing to the sport played, show specific signs of adaptation. One major system limiting successful adaptation to the effects of sport participation is the cardiovascular system. Functional capacity of the cardiorespiratory system is identified with aerobic capacity [1, 5]. Performing standardized graded exercise tests provide an essential opportunity to analyse individual responses of the cardiovascular system from the functional and diagnostic point of view. It is apparent that athletes under study display high characteristics in functional capacity (PWC_{170}, maximum oxygen consumption according to the assessment scales of Shvartz et al. [12] in both groups ("PD" and "HD" older and younger track and field athletes).

Male athletes of both groups (younger and older groups of athletes) showed a higher frequency of traumas than females. Comparison of the frequency of health disorders in persons under observation revealed a relatively higher incidence of health problems among the subjects with longer personal sport histories.

CONCLUSIONS

Certain inherent risks are associated with sports physical activity. The athletes and coaches should be aware of these risks and take steps to minimize them. Advanced planning, proper equipment and facilities, and physician recommendations for exercising the sportsmen with health disorders help to reduce the possibility of producing serious health problems and long-term disabilities and handicaps. The high percentage of persons with health disorders among subjects under study indicates that only close collaboration between athletes, coaches and physicians could help to prevent serious disabilities and diseases of sportsmen.

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