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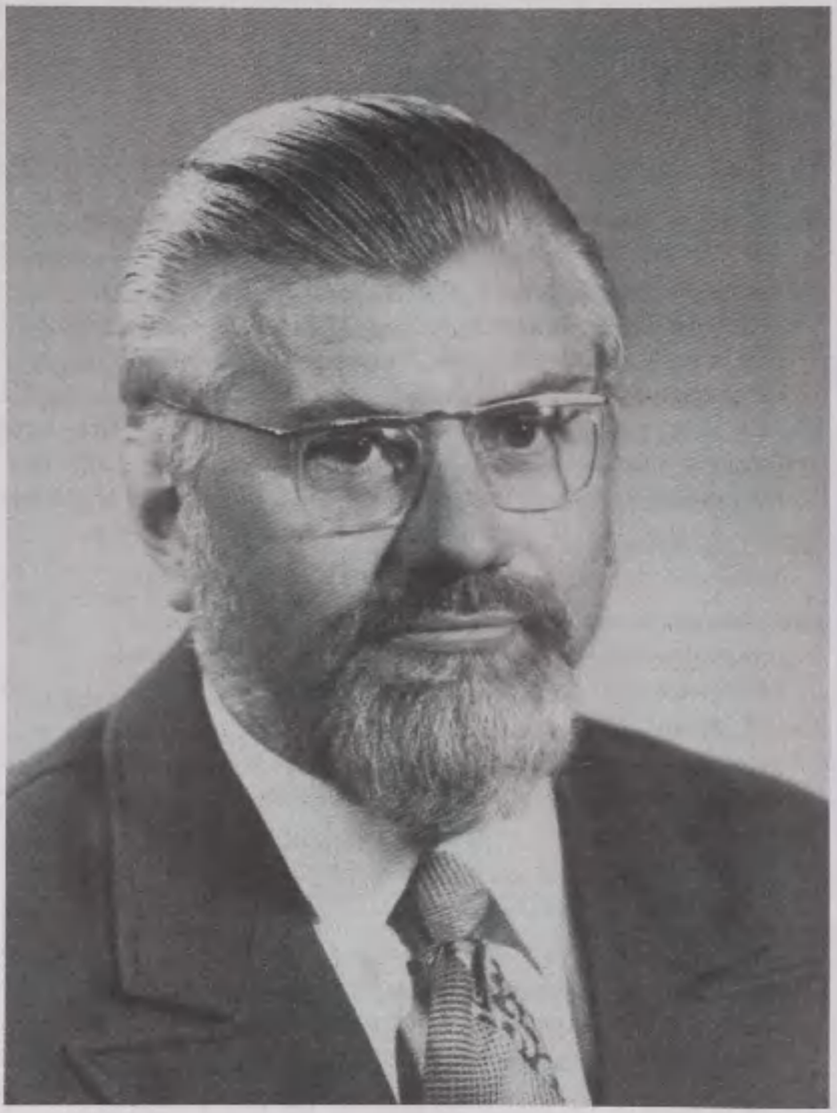

IN MEMORIAM
ATKO VIRU
7 September 1932 – 21 October 2007

The University of Tartu is mourning the *grand old man* of sport sciences whose contribution to research has put him on the map not only in Estonia but on a much wider scale.

Atko Viru graduated from the University of Tartu in 1955 as teacher of pysical education and sport and entered the postgraduate programme in the Department of Physiology. He was awarded the degree of Candidate of Sciences (equalling to PhD) in Biology in 1963 and the degree of Doctor of Biology in 1970. The teaching career at the University of Tartu led Atko Viru up to the professor's position in 1973. Atko Viru was the Dean of the Faculty of Exercise and Sport Sciences from 1973 to 1989. The retirement in 1998 as *professor emeritus* did in no way stop Atko Viru from promoting research in its many-sided forms of article-writing, lecturing and supervising. The community who can call Atko Viru their true Teacher, is considerably large and includes 40 PhD degree holders whose theses he supervised.

The number of research articles with Atko Viru's name as the single or co-author exceeds 500, several of them have been and still are enjoying extensive international recognition and high citation indices. He is also author or co-author of 12 monographs, including major works on adaptation and biochemical monitoring of sports training, published by CRC Press and Human Kinetics.

Atko Viru has been member of editorial boards of a number of research journals, e.g. *International Journal of Sports Medicine; Sport Medicine, Training, Rehabilitation; Biology of Sport; Coaching and Sport Science Journal; Medizina Sportiva; Medicina dello Sport.* This list includes the present publication, *Acta Kinesiologiae Universitatis Tartuensis*. Besides, Atko Viru was frequently an invited lecturer at international research events all over the world.

Atko Viru was Professor in the true sense of the word, finding it his task to improve matters beyond *alma mater*. He was one of the group of individuals striving to restore the activities of the Estonian Olympic Committee following the regaining of independence of Estonia and was elected Vice-president of the EOC (1989–2000). He also introduced the movement of Olympic Academies in Estonia and was the first President of the EOA (1989–2001). Atko Viru was involved in several other movements of major public impact.

Atko Viru was honoured for his merits and contribution on several occasions: he was awarded the prize of the International Olympic Committee for promoting Olympism in 1996 and received the Order of Red Cross and the Prize for Lifelong Contribution in Sport in 2001 from the Republic of Estonia. He was elected honorary doctor of the Lithuanian Academy of Physical Education.

Atko Viru will be remembered by numerous friends and colleagues worldwide for his erudition, extensive range of scientific interests and excellent oratorical skills, and also as a considerate and warm-hearted person who was always ready to help young researchers and advise the experienced ones.

STEROID HORMONE RESPONSES TO INTENSIVE PROLONGED ENDURANCE EXERCISE IN WOMEN

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ABSTRACT

The purpose of this study was to examine and describe the response of select steroid hormones, which help to regulate anabolic and catabolic physiologic function, in women after an intensive prolonged bout of endurance exercise. Ten trained women ran on a treadmill at an intensity approximating their ventilatory threshold until the point of volitional fatigue. Bloods were taken to assess cortisol (C), total testosterone (TT), and DHEA-S at rest, volitional fatigue (immediately post-exercise), 30, 60, and 90 min post-exercise (PE) and 24 hours PE. All hormones were increased significantly immediately PE compared to baseline resting levels ($p = 0.001$), then returned to near resting levels by 90 minutes PE. At 24 hours PE, hormonal concentrations decreased to below pre-exercise resting levels, although these reductions only approached statistical significance ($p<0.10>0.05$). Findings suggest that exercise-induced increases in cortisol, DHEA-S and testosterone are elevated in the early recovery period following termination of intensive prolonged exercise, but the levels may subsequently decrease after 24 hours, which potentially may affect skeletal muscle recovery from such endurance exercise.

Key words: Catabolic, Anabolic, Physical Activity, Endocrine, Female

INTRODUCTION

Anabolic hormones exert a biological effect on almost all tissues in the human body. In relation to exercise and training adaptation, anabolic hormones are important for the growth and maintenance of skeletal muscle, enzymatic proteins, bone, and red blood cells as well as helping to enhance neural function [16, 19]. Testosterone and the sulfated form of dehydroepiandrosterone (DHEA-S) are key steroid-based anabolic hormones that in a large part induce these biological effects in women. Testosterone is considered the more potent of these hormones; while, DHEA-S is a weaker anabolic hormone whose direct physiologic function in young healthy individuals is not well understood. Nevertheless, it is known that the peripheral tissue conversion of DHEA-S is the major source of endogenous testosterone in women [3].

Cortisol is a steroid-based catabolic hormone secreted from the adrenal cortex in response to physical and psychological stress. Exercise and severe hypoglycemia (which can be a result from performing prolonged exercise) are two of the many physical stressors that stimulate the production and secretion of cortisol. The response of cortisol to exercise is dependent upon the duration and intensity of exercise [15]. At intensities greater than 60% of maximal aerobic capacity, the secretion rate exceeds the tissue uptake and circulating cortisol concentration increases. While cortisol concentration increase during exercise, the major actions of cortisol seem to occur primarily in the recovery from exercise [4, 21]. Some of these effects are to stimulate protein breakdown in skeletal muscle, breakdown of triglycerides in adipose tissue, as well as act to stimulate glycogenesis and gluconeogenesis in the liver [15, 19, 21].

Research on the effects of prolonged endurance exercise on hormones such as cortisol, DHEA-S, and testosterone has been less frequently studied in women than in men. This has occurred even though the involvement of women in prolonged endurance sporting activities has grown exponentially in the last few decades. Research appears especially lacking relative to intensive prolonged endurance exercise (similar to sporting competitions [e.g., marathons]) which places great demands and stresses on athletes. This is an important consideration as intensive competitive exercise has been shown to provoke differing endocrine responses than non-competitive exercise situations [8]. Therefore, the purpose of this study was to examine and describe the response of select steroid hormones which help to regulate anabolic and catabolic function in women after an intensive prolonged bout of endurance exercise.

METHODS

Subjects

Young, healthy females ages 18 to 26 participated in this study (n = 10). The subjects were aerobically trained endurance runners or triathletes, having trained for a minimum of 2 years, 5 days per week for at least 30 minutes a day prior to participation in this study. They were free of any known endocrine disorders. Subjects were asked to make three visits to the Applied Physiology Laboratory at the University of North Carolina at Chapel Hill to participate in experimental research sessions. All measures were taken during the follicular phase of the subjects' menstrual cycle as confirmed by oral temperature records. Further data of subject characteristics appears in Table 1.

Table 1. Demographic characteristics of the subjects

Measurement	Mean	Standard Deviation
Age (years)	23.5	2.1
Height (cm)	165.7	6.2
Mass (kg)	59.8	3.8
% Body Fat	19.4	3.7
Years of Training	6.5	3.1
VO_{2max} (L/min)	3.18	0.22
VO_{2max} (ml/kg/min)	56.2	2.7
VO_2 at VT	2.39	0.27
VO_2 at VT as % of VO_{2max}	76.2	6.2

Session One

Subjects completed a written informed consent waiver, a training history questionnaire, and a medical history questionnaire. Physical screenings involved a resting 12-lead echocardiogram (ECG), blood pressure measurements, and basic assessments of pulmonary, circulatory, and orthopedic function. Height in centimeters (cm) and body mass in kilograms (kg) were recorded. Skinfolds were assessed at three sites (tricep, supra-iliac, and femoral) using Harpenden skinfold calipers (Creative Health Products, Ann Arbor, MI). The Jackson-Pollock skinfold regression equation was used to estimate body composition [11].

A modified Astrand treadmill test (as reported by Pollock and Wilmore 1990) [17], using a Quinton Q65 series 90 treadmill (Quinton Instrument Company, Seattle, WA) was used to determine each subjects maximal oxygen uptake (VO_{2max}). The starting speed for the treadmill was determined from information provided on the training history questionnaire. Respiratory gases [oxygen uptake VO_2], carbon dioxide production) were measured using a TrueMax 2400 analyzer system (Parvo Medics, Sandy, UT), and data were collected every 15 seconds during exercise. Heart rate (HR) in beats per minute (bpm) was recorded every minute of exercise and rating of perceived exertion (RPE) was recorded at the end of every three minutes. The grade of the treadmill was kept constant at 1.5%, while the speed was increased incrementally every 3 minutes. The VO_{2max} test was terminated upon volitional fatigue of the subject. Subjects were determined to have reached VO_{2max} based upon previously published criteria [18].

Session Two

Prior to the second session, subjects were asked not to participate in any strenuous activity for 24 hours before, not to ingest any alcohol for 24 hours before, or to ingest any caffeine for 12 hours before the session. For the three days prior to the second session, the subjects were asked to eat a diet in which at least 60% of the caloric intake was from carbohydrate. A 3-day dietary recall was used at the beginning of the second session to ensure the subjects' diet followed these guidelines.

Subjects reported to the laboratory at least 72 hours after the cessation of the maximal exercise test in session one. The second testing session took place between 12:00 and 15:00 hours, a time in which cortisol concentrations are relatively stable according to its diurnal circadian rhythm [2]. Subjects reported to the laboratory in a 2.5 hour fasted state. A 24-gauge catheter (Johnson and Johnson Medical, Arlington, TX) was inserted in an antecubital vein for blood sampling. Subjects then rested in a supine position for 30 minutes, and a baseline pre-exercise blood sample (3 ml) was taken. Subjects were next fitted with a Polar heart rate monitor (Polar, Finland) and began a 10 minute warm up session. The warm up session consisted of cycling on a Monark cycle ergometer (Monark 814 Ergomedic, Sweden) for 3 minutes at 60 revolutions per minute (rpm), 1 kp resistance, followed by 5 minutes of stretching. The subject concluded the warm up session with 2 minutes of light walking on the treadmill.

The subjects then ran on the treadmill at a speed to elicit their predetermined ventilatory threshold (± 5%) until reaching volitional fatigue. Ventilatory threshold (VT) for each subject was determined from their VO_{2max} test and represented the point at which ventilation began to rise exponentially in response to linear increases in VO_2 [18]. Respiratory gases, HR, and RPE data were collected at 5, 30, and 60 minutes (2 minute sampling period) during the exercise to monitor the intensity. After 60 minutes, these measures were taken every 15 minutes and again at volitional fatigue. When the subjects reached volitional fatigue, a post-exercise blood sample (3 ml) was immediately taken. Next the subjects rested in a supine position for 90 minutes. Additional blood samples (3 ml) were taken at 30, 60, and 90 minutes during this post-exercise recovery period. Throughout the exercise subjects were verbally encouraged and as they approached the point of fatigue, this encouragement was increased to simulate what might occur during a sporting competition. Also, throughout the exercise and recovery period the subjects were allowed to drink water *ad libitum*.

Session Three

Session three took place 24 hours after the cessation of the prolonged treadmill run. The subjects were instructed to not participate in any strenuous activity between session two and session three, and not to ingest any alcohol or caffeine during this time. Upon reporting to the laboratory, the subject rested in a supine position for 30 minutes, at which point the final blood sample (3 ml) was taken.

Biochemical Analysis

Blood samples were collected into sterile vacutainer tubes (BD Vacutainer Systems, Franklin Lakes, NJ) and placed on ice immediately.

A small sample of whole blood was transferred into EDTA treated tubes (BD Vacutainer Systems) to be analyzed for hematocrit and hemoglobin. Plasma volume shifts were calculated using the Dill and Costill [5] equation from hematocrit and hemoglobin to account for hemoconcentration of the blood. Hematocrit was determined in triplicate using the microcapillary tube method. Hemoglobin was colormetrically determined using a cynamethoglobin reaction quantified on a spectrophotometer (Milton Roy Spectronic 1201, Rochester, NY). The remaining blood samples were later centrifuged at 3000 x g at 4° C to separate sera. The separated serum was stored in cryo-freeze tubes at –80°C until analysis. Blood serum was analyzed using single antibody solid phase radioimmunoassay procedures (triplicate determination) with ^{125}I, using commercially available kits for the determination of cortisol, total testosterone, and DHEA-S (DPC Inc., Los Angeles, CA).

Lactate was assessed in duplicate on select blood samples using dry chemistry colormetric procedures (Johnson & Johnson Inc., New York, NY). Quantification of these procedures involved a "Vitros" DT-60 analytical unit (Johnson & Johnson).

Statistical Analysis

Statistical analyses were conducted using the "Statistica" software program (Statsoft, Tulsa, OK). Descriptive statistics were determined for subject characteristics, including; age, height, body mass, percent body fat, and VO_{2max} (see Table 1). Significant changes in hormone concentrations across exercise and recovery time were assessed by repeated measures analysis of variance (ANOVA) with Tukey HSD post hoc tests being applied where appropriate. The level of statistical significance was set at $p \leq 0.05$.

RESULTS

Prolonged Exercise to Volitional Fatigue

Subjects ran on the treadmill until volitional fatigue, which occurred at a mean time of 75.1 ± 22.2 minutes (± SD). All subjects were able to run for the minimum time required by the protocol of the study (45 minutes). The mean running speed for the subjects was 11.5 ± 0.7 km/hour. Data for the subjects displaying mean HR, VO_2, %VT, lactate, and RPE during the prolonged run to volitional fatigue are displayed in Table 2. Percent VT ($[VO_2/VO_{2\ VT}] \times 100$) was the measured VO_2 of the subject at each sampling time divided by the observed VO_2 of the subject for their individual ventilatory threshold as determined from the VO_{2max} test. Lactate concentration was measured only in the blood sample taken at volitional fatigue and used to further confirm that the subjects were exercising at an intensive level during the prolonged run.

Table 2. Select results (mean ± SD) for the prolonged run to volitional fatigue (*indicates significant differences from minute 5 values, $p \leq 0.05$)

Measurement	Minute 5	Minute 30	Volitional Fatigue
HR (bpm)	164.2 ± 6.8	171.6 ± 8.3	177.3* ± 11.0
VO_2 (L/min)	2.23 ± 0.17	2.28 ± 0.21	2.36* ± 0.25
% VT	93.7 ± 5.6	95.6 ± 6.1	98.8* ± 7.7
Lactate (mM/L)	–	–	4.3 ± 0.6
RPE	11.5 ± 1.0	12.9* ± 1.2	15.8* ± 1.8

Hormonal Responses

Radioimmunoassay procedures specific to each hormone were performed to determine the hormone concentrations in each blood sample. Assay quality control measures suggest the analyses were technically accurate and valid (i.e., between and within assay coefficient of variances were less than 8.5%, and variance from internal control samples were less than 5.0%). Table 3 displays the results for each hormone at the six blood sampling time points measured.

Table 3. Hormone concentrations for cortisol, total testosterone (T), and DHEA-S before and after the prolonged run to volitional fatigue (Mean ± SD) (* indicate a significant difference from pre-exercise values, $p \leq 0.05$)

Hormone	Pre-exercise	Volitional Fatigue	30 min Post	60 min Post	90 min Post	24 Hours Post
Cortisol (μg/dL)	21.5 ± 9.1	32.6* ± 10.9	32.1* ± 13.8	28.3 ± 13.6	25.7 ± 11.8	16.4 ± 9.6
Total T (ng/dL)	17.7 ± 7.1	29.0* ± 10.1	24.2 ± 6.5	22.1 ± 8.5	18.9 ± 6.8	15.7 ± 6.9
DHEA-S (μg/dL)	122.4 ± 71.8	173.2* ± 81.9	152.2* ± 79.4	141.0 ± 78.6	146.9* ± 86.7	97.2 ± 73.4

Cortisol, total testosterone, and DHEA-S all showed a similar response pattern over the sampling times used in the study. There was a significant ($p = 0.001$) hormonal increase as a result of the exercise (i.e., at volitional fatigue), with concentrations being significantly elevated over pre-exercise resting levels. The general trend in the hormonal data was to maintain this increase up to 30 minutes into recovery, and then concentrations began to decrease, and continued to decrease until 90 minutes post exercise (approaching pre-exercise levels). At 24 hours post exercise, concentrations had decreased to below pre-exercise resting levels; although, these hormonal reductions only approached statistical significance [$p<0.10>0.05$).

Plasma Volume Measurements

As noted, whole blood determinations of hematocrit and hemoglobin were performed to track changes in plasma volume during and after the prolonged run to volitional fatigue. The subjects had a significant, but transient, loss of −8.0% (± 5.5) plasma volume from pre-exercise to volitional fatigue ($p = 0.003$). In relation to the magnitude of the changes observed in the hormonal concentrations, these changes in plasma volume were relatively minor. This suggests hemoconcentration was not the main factor altering hormonal levels during exercise. A small degree of hemodilution was observed during the recovery blood sampling (30 to 90 minutes post exercise) as plasma volume was increased (+2.1% ± 3.5 to +3.3% ± 2.5) slightly. At 24 hour post exercise plasma volume was reduced (–2.4% ± 4.4) from pre-exercise resting levels, but this was not statistically significant ($p<0.10>0.05$).

DISCUSSION

The purpose of this study was to examine and describe the response of select steroid hormones to an intensive prolonged bout of endurance exercise in women. Specifically, the intent was to determine if these hormones behave in a similar fashion in women as they do in men performing endurance exercise. This research question was addressed because of a limited amount of investigative work available on this aspect of endocrinology in women who perform intensive exercise training (i.e., of a competitive nature). The findings suggest cortisol, DHEA-S and testosterone are increased in response to this form of exercise and remain elevated in the early recovery period following termination of the activity. The cortisol, DHEA-S and testosterone responses are in accordance with what the limited previous literature has found for women performing exercise of a non-competitive nature [1, 12, 14, 20] as well as that involving competitive exercise [13].

Relative to similar research conducted in men, the present findings for the steroid hormone responses are remarkably comparable in nature. The published findings of Keizer et al. [13], Hoogeveen and Zonderland [10], Duclos et al. [6], Hackney and Viru [9], and Daly et al. [4] all show alike hormonal changes. Although, it is important to recognize the magnitude of some of the absolute hormonal concentrations observed in these studies vary from those of the present data due to gender related differences [3, 19].

Perhaps the most interesting finding within these results was the tendency for these hormones to be reduced 24 hours into the recovery from the intensive prolonged exercise. Each of these hormones has a vital role in the physiological functioning of the human body. Their anabolic and catabolic actions help to bring about the hormonally mediated phenotype changes necessary for the training adaptations of skeletal muscle in the myo-plasticity process [2]. It is unclear if the observed reductions are a necessary feedback regulatory suppression following the acute substantial hormonal increases in response to the exercise bout [22], of if perhaps they represent a stress reactivity within these endocrine parameters and a somewhat dysfunctional response [7, 8]. This question needs to be addressed fully in future research.

CONCLUSION

The responses to prolonged endurance exercise for all three hormones measured in this study were normal in relation to what previous research has established. The findings suggest that steroid hormones remain elevated in the early recovery period following the termination of the activity, but may be reduced by 24 hours afterwards. Additional research is needed to better understand the relationship between these endocrine responses to intensive prolonged endurance exercise and the resultant physiological responses within the skeletal muscle.

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EFFECT OF SUBMAXIMAL PHYSICAL EFFORT DURING "AEROBICS" ON PERIPHERAL CONCENTRATION OF LEPTIN IN WOMEN

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ABSTRACT

The aim of the research is to evaluate the effect of long-lasting submaximal physical effort ("aerobics" – physical exercises performed to music) on blood concentration of leptin in women. The experiment (single 60 minute aerobics session) involved 11 women in the age between 30 and 50. Blood samples, collected before and after physical effort, were assayed in respect with the concentration of leptin, lactic acid (ŁA), glucose, free fatty acids (FFA), insulin (I), growth hormone (GH), testosterone (T) and cortisol (C). Additionally determined parameters comprised body mass measured before and after effort, and temperature taken in the auditory canal on tympanic membrane and on forehead. Heart rate (HR) was recorded in a continuous mode during the effort. The average level of the performed effort was approximately 70%. HR_{max} caused significant decrease in body mass and rise in temperature of the objects. Decrease in glucose concentration was accompanied by characteristic rise in FFA. Corresponding relations manifested themselves in case of I and GH, i.e. statistically significant drop in I and rise in GH. No essential differences were reported between concentrations of cortisol, testosterone and leptin measured “before” and “after” the effort. Long-lasting submaximal physical effort, in the presence of energy provisions and physiological balance, did not upset the anabolic-catabolic balance of the organism, and loss of body mass is primarily related to dehydration resulting from thermoregulation by means of water loss through perspiration. Changes in blood concentrations of insulin and growth hormone show how regulation of the energetic profile of metabolism is oriented towards conservation of carbohydrates and intensification of lipolysis, and emphasise their counter-regulatory functions in relation to glucose. Analysis of results did not provide for any relation between the general energy consumption, changes in the investigated hormones and leptin concentration in regulatory mechanisms. It can be assumed that the proposed effort (energy consumption) was a hardly effective stimulus, sufficient to discover role of leptin in the afferent signalization for the hypothalamic hunger centre, which additionally highlights the fact that the energy balance in women performing exercises is conserved.

Key words: leptin, metabolic and hormonal response, submaximal physical effort

INTRODUCTION

Proper lifestyle, the key component of which is physical activity, is one of the most significant factors underlying health. Thus, importance of physical activity in preventing civilization diseases, such as obesity, is referred to in numerous works. Therefore, recent years witnessed particular ascent in importance of research related to effect of physical effort on mechanism regulating proper metabolism.

Leptin is one of the most important and at the same time one of the best known peptides secreted by adipocytes. This peptide, with weight of 16 kDa and consisting of 167 amino-acids, is produced by the ob gene [53]. In humans, similarly to other mammals, leptin is mainly generated in mature adipocytes of the adipose tissue [3, 53]. The protein, in smaller quantities, is also produced in e.g. placenta, brain, stomach and lactiferous gland [3, 27]. Biosynthesis of leptin in the adipose tissue depends on the adipocyte size and to a great extent it is regulated by insulin. Synthesis of leptin as well as its secretion from fat cells, is monitored by the insulin level [7, 28, 35, 44]. Discovery of leptin stimulated investigations into mechanisms which contribute to maintenance of energy homeostasis in organisms [3]. It explicitly results from research involving both animals and humans that leptin plays an essential role in regulation of the food uptake and the basal metabolic rate [2, 12, 13, 19, 24, 41]. Furthermore, it is vitally important in neurohormonal regulation of the above processes, where it acts as a hormone signalling the central nervous system that energy supplies of the organism are reduced and therefore it can be considered a specific barometer of intra-body energy balance [5, 21, 22].

Relationship between the concentration of leptin and the concentration of other hormones was reported by a huge number of researchers. It was determined that catecholamines limit synthesis of leptin in the adipose tissue, and thus its concentration in blood serum [9, 11]. A lot of data, as it was mentioned above, support the strict interrelationship between leptin concentration and serum concentration of insulin, as well as the interrelationship between peripheral concentration of leptin and tissue sensitivity to insulin [1, 23, 29]. Also glucocorticosteroids play an important role in the physiological regulation of leptin concentration [16]. It was demonstrated that cortisol stimulates production of leptin. Additionally, research of Ur et al. [47] showed that obese people may develop not only hyperleptinemia but also leptin resistance on account of chronic hypersecretion of cortisol. Another hormone, which is reported to be strongly related to secretion and serum concentration of leptin is growth hormone (GH). Growth hormone exerts intensive influence on metabolism of proteins, lipids and carbohydrates. In some cases, a direct effect of growth hormone has been clearly demonstrated, in others, IGF-I is thought to be the critical mediator, and again in some cases it appears that both direct and indirect effects are at play. In general, growth hormone stimulates protein anabolism in many tissues. This effect reflects increased amino acid uptake, increased protein synthesis and decreased oxidation of proteins. Growth hormone enhances fat consumption by stimulating triglyceride breakdown and oxidation in adipocytes. Growth hormone is one of a battery of hormones that serves to maintain blood concentration of glucose within a normal range. Growth hormone is often said to have anti-insulin activity, because it suppresses the abilities of insulin to stimulate uptake of glucose in peripheral tissues and enhance glucose synthesis in the liver. Somewhat paradoxically, administration of growth hormone stimulates insulin secretion, leading to hyperinsulinemia [38, 39, 46].

Research support the negative interrelationship between the growth hormone and leptin concentrations [15, 33]. The above specified facts indicated leptin to be the signal of the body feeding status, which helps to control secretion of the growth hormone.

Thus, research results prove biochemical parameters, involved in maintenance of energy balance, to be physiological regulators of leptin concentration. Furthermore they support the hypothesis under which leptin is a balance indicator in the field of human physiology [17].

Discovery of leptin [53] is partly responsible for many experiments conducted with the purpose of gaining better understanding how this hormone functions in human body, and the primary aim of a number of these experiments was to investigate into changes of leptin concentration resulting from single physical effort as well as long-lasting training. At the present moment the effect of physical effort on leptin concentration is still not fully understood [8]. Some researchers have reported that physical effort may lead to drop in leptin concentration which they ascribed to such factors as duration of the effort and appropriately high energy consumption [8, 18, 26, 31, 36, 51, 52]. However others pointed to lack of changes in leptin content induced by physical effort [8, 30, 42, 43, 48, 55].

The fact that blood concentration of leptin depends on tissue sensitivity to insulin [27, 28, 34, 35, 44], on fat content in the subdermic fat [6, 10, 25, 54] and high blood concentration of this hormone in people suffering from obesity [14, 40, 50], and also interrelationship between blood concentration of leptin and amount of energy supplied in food [32] allow us to think that intensified energy consumption may be considered one of the factors which affect leptin blood concentration in human body.

METHODS

Subjects

The experiments involved 11 healthy women, aged 30–50, with average weight 60.5 ± 5.32 kg, height 165.0 ± 4.75 cm and BMI falling in the range 22.6 ± 2.37. The examined persons do not actively practise any sports, and they only participated in recreational "aerobics". The training was provided by an authorised person in accordance with a programme for untrained people [4, 20, 37, 45].

The experiments were approved of by the Ethics Committee of the University of Physical Education in Warsaw. Participants of the experiment were informed about the aim and approach and possibility to withdraw at any time during execution of the experiment. The objects submitted their consent to be included in the experiment in writing.

Experimental design

Physical effort involved „aerobics" exercises performed to music for 60 minutes (from 6 p.m. to 7 p. m.) in accordance with a standard programme, i.e. intensity, movement form and structure, were adapted to averaged age of women subjected to the experiment [4, 20, 37, 45] (Figure 1).

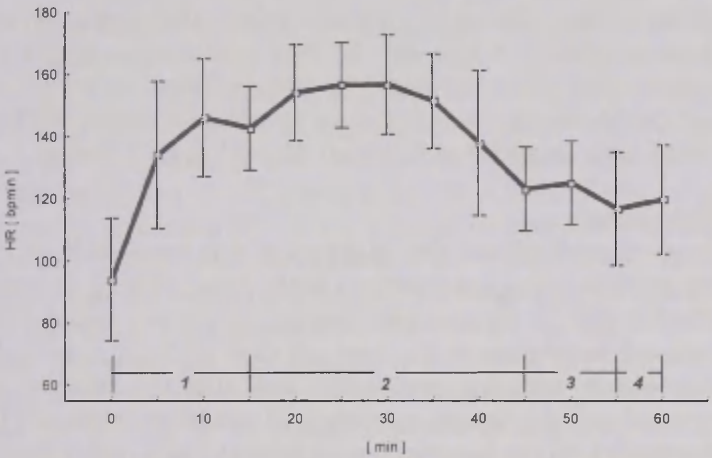

Figure 1. Heart rate (HR) during 60 minute exercises performed to music („aerobics"), mean values (± SD) for n = 11; 1, 2, 3, 4 – single phases of the exercise cycle. Description: **1. Warm-up:** 10–15 min. (music rhythm: 126–139 beats per minute (bpm) of the piece). Aim: preparing body for the effort; stretching, in particular of those muscles which are to be subject to main load during the training, in the final part of the effort. **2. Specific aerobics** (cardio): 35–45 min. (music rhythm e.g. low impact 132–140 bpm, hi/lo: 136–152 bpm, step: 126–136 bpm, latino, brasilian: 120–130 bpm). Aim: performance of exercises with the specified intensity within the target zone of the training. **3. Strengthening** (muscles): 5–10 min (music rhythm: 110–130 bpm). Aim: exercises oriented to strength

and endurance training, which involves a greater number of repetitions and shorter breaks. **4. Closing part:** about 5 min. (music rhythm: 80–100 bpm). Aim: restoring stable heartbeat, down to resting heartbeat, and increase in the range of joint mobility. Calming and stretching physical exercises alternatively with relaxation and respiratory exercises.

Blood collection and biochemical analysis

The selected parameters were determined on blood samples (from the basilic vein and fingertip) collected before the effort and immediately after its completion.

The following parameters were determined in the collected samples:

1. concentration of lactic acid (Lange set) in arterialised capillary blood,
2. leptin (IBL, Germany), insulin (IBL, Germany), growth hormone (hGH-EASIA BIOSOURCE, Germany), cortisol and testosterone (IBL, Germany) in venous blood. Assay of the selected hormones was based on immuno-enzymatic methods using ready sets with an automatic Micro Leader 3 readers.

Other parameters

Assessment of physiological cost of the effort was based on heart rate (HR) registration using sport-testers (S610, Polar Electro Oy, Finland). Contribution of the anaerobic energy component during effort was evaluated in relation to the concentration of lactic acid (LA). Body temperature was measured before and after the effort in the auditory canal on the tympanic membrane (Tty) and on forehead (Th) using thermistors (Ellab, Copenhagen, Denmark). Body mass (electronic scales TANITA Bf-666) and height were applied for determination of BMI for all the objects. The anabolic-catabolic indicator (T/C) were calculated as per the below formula:

$$T/C = \frac{testosterone(nmol/l)}{cortisol(nmol/l)} x1000$$

Statistical analysis

The results were processed by means of basic statistical methods taking into account arithmetic means, standard deviations, simple correlation coefficients, significance of differences between mean values in t-Student test for dependent features. All calculations were performed using STATISTICA^{TM} (v.5.5, StatSoft).

RESULTS AND DISCUSSION

Figure 1 shows average HR during one hour physical exercises performed in accordance with “aerobics” principles. It allows to assess the effort as submaximal load as in all cases the heart rate did not reach its maximum value, and on average it represented about 70% of the maximum heartbeat, which approximately corresponds to oxygen consumption on the level of 60% $V0_2max$ of the objects. Nevertheless, the effort induced considerable ($P > 0.0001$) increase in LA concentration in the objects, from 1.3 ± 0.38 to 5.5 ± 1.25 mmol/l (Table 2). All cases were accompanied by body mass decrease (from 0.2 to 0.7 kg), on average in respect to the group 0.4 ± 0.17 kg (Table 1). This fact may mainly ascribed to dehydration resulting from perspiration, which is related to thermoregulation. Average body temperature increase (Tc) amounted to 0.48 ± 0.17 °C; increase from 35.82 ± 0.41 before, to 36.30 ± 0.21°C after aerobics ($P > 0.02$) (Table 1, Figure 2). Similarly significant ($P < 0.02$) increase in temperature measured on forehead (TH) was accompanied by insignificant increase in temperature measured on tympanic membrane (Tty) (Table 1). Smaller increase in body temperature was reported for larger loss of body mass following the exercises. The correlation between the loss of body mass and temperature increase was negative. Long-lasting effort revealed changes in the metabolic profile of supplying energy during physical exercises. Table 2 shows decrease in blood concentration of glucose from 96.6 ± 12.26 mg/dl before aerobics to 78.1 ± 7.78 mg/dl after aerobics ($P < 0.001$). On the other hand, considerable ($P < 0.002$) increase in FFA concentration, with 0.229 ± 0.24 mmol/l is observed before the effort to 0.471 ± 0.38 mmol/l after the effort. This observation is supported by changes in concentrations of insulin and growth hormone (Table 2, Figure 4). As hormones providing for counter-regulation in comparison to glucose, their after-effort changes are negatively correlated, i.e. drop in insulin concentration is accompanied by increase in GH blood concentration. The blood concentration of insulin dropped, on average from 21.95 ± 13.55 μIU/ml before the effort to 6.86 ± 8.47 μIU/ml ($P > 0.004$) subsequently. No changes in concentrations of cortisol and testosterone were noted

(Table 2, Figure 5). At the same time it has to be emphasized that the anabolic-catabolic (T/C) indicator, calculated using testosterone and cortisol concentrations, showed a rising trend (Table 2, Figure 6). It underlines the fact of intact intra-body metabolic balance between breakdown and synthesis by means of physical effort applied in our research. This fact may correspond to statistically insignificant decrease in after-effort blood concentration of leptin (Table 2, Figure 6). Before the effort, average leptin concentration was 4.08 ± 1.31 ng/ml, and after an hour exercises – 3.03 ± 0.92 ng/ml.

Table 1. Body mass, BMI, temperature measured on tympanic membrane (Tty) and on forehead (Th) and mean body temperature (Tc)[1] before and after 60 minute "aerobics" (mean values ± SD for n = 11).

Parameter	before "aerobics"	after "aerobics"	significance level
body mass (kg)	60.5±5.32	60.1±5.38*	P<0.001
BMI (kg/m^2)	22.18± 1.91	22.04±1.93*	P<0.001
T_{tv} (° C)	36.87±0.46	36.96±0.47	–
T_h (° C)	34.24±0.73	35.06±0.44*	P<0.02
T_c (° C)	35.82±0.41	36.30±0.21*	P<0.02

[1]mean body temperature based on the formula: Tc = (0.4 x Th) + (0.6 x Tty), [49].
*values significantly different from those determined before "aerobics"

Table 2. Mean (± SD) values of metabolic and hormonal parameters determined before and after "aerobics".

Parameter	Before "aerobics"	After "aerobics"	Significance level
Lactic acid (mmol/l)	1.3±0.38	5.5±1.25*	P<0.0001
Glucose (mg/dl)	96.6±12.29	78.1±7.78*	P<0.001
FFA (mmol/l)	0.299±0.24	0.471±0.38*	P<0.002
Leptin (ng/ml)	4.08±1.31	3.03±0.92	–
Insulin (μIU/ml)	21.95±13.55	6.86±8.47*	P<0.004
Growth hormone (ng/ml)	2.79±1.89	5.51±3.83*	P<0.01
Testosterone (ng/ml)	1.17±0.21	1.23±0.28	–
Cortisol (nmol/l)	217.3±156.0	211.2±151.3	–

* values significantly different from those determined before "aerobics".

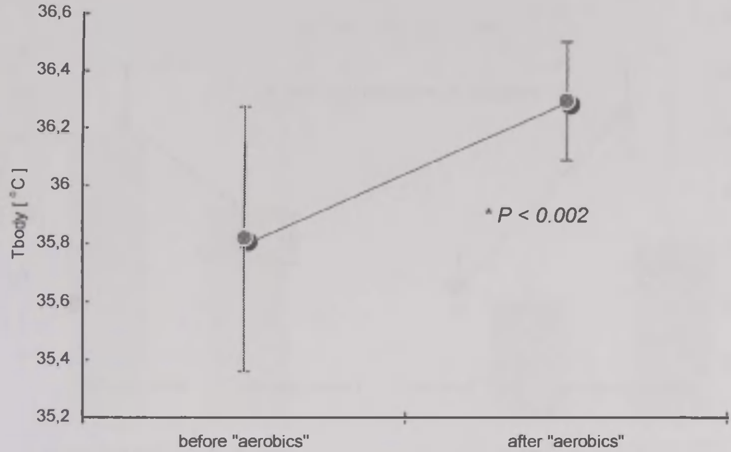

Figure 2. Mean (± SD) body temperature (T_{body}) before and after 60 minute „aerobics". (*P < 0.002 – difference significant in terms of statistics in relation to value measured before "aerobics").

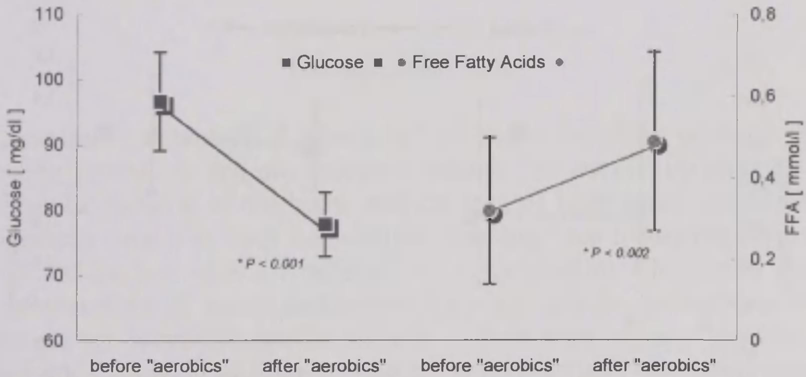

Figure 3. Mean (± SD) blood concentration of glucose and free fatty acids (FFA) before and after „aerobics" (*P < 0.001 – value significantly lower and *P < 0.002 significantly higher than the value measured before "aerobics").

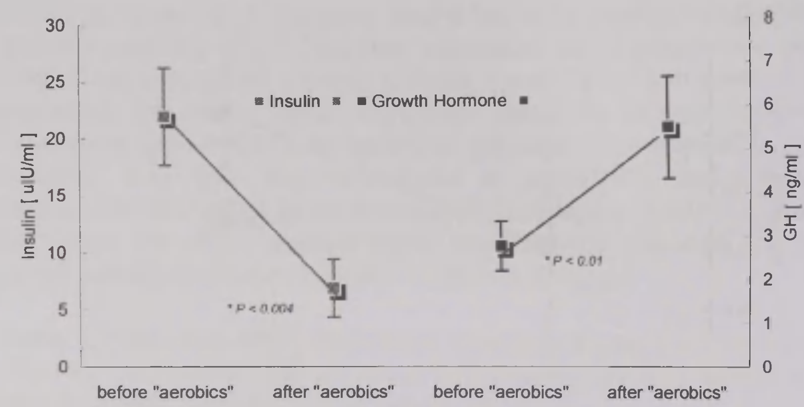

Figure 4. Mean (± SD) blood concentration of insulin and growth hormone before and after 60 minute "aerobics" (*P < 0.004; *P <0.01 – values significantly lower and significantly higher than the value determined before exercises).

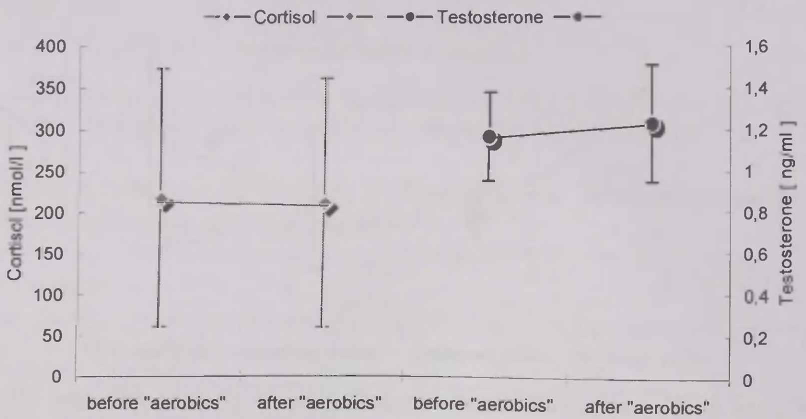

Figure 5. Mean (± SD) blood concentration of cortisol and testosterone before and after 60 minute "aerobics".

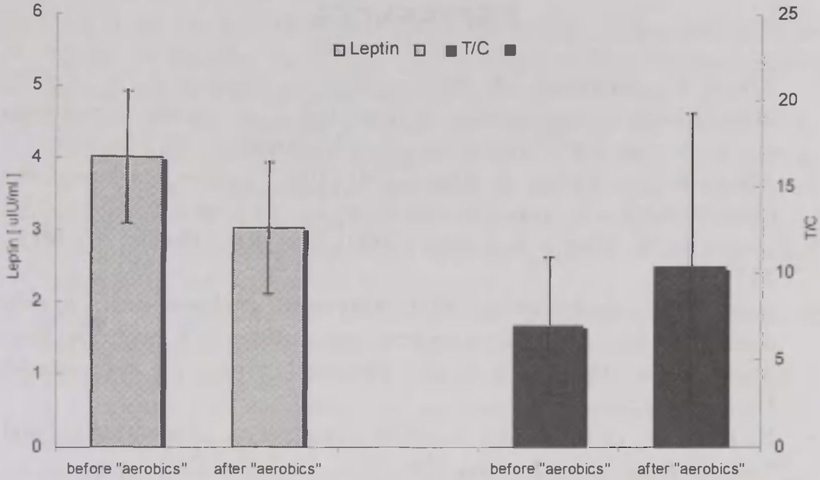

Figure 6. Mean (± SD) blood concentration of leptin before and after "aerobics". Anabolic-catabolic indicator (T/C) determined before and after one hour training.

CONCLUSIONS

Long-lasting submaximal physical effort, performed in the presence of energy provisions and physiological balance, did not disturb anabolic-catabolic balance of the body, and the loss of body mass should be primarily related to body dehydration resulting from thermoregulation effected by loss of water on account of perspiration. Changes in the concentrations of insulin and growth hormone indicate reorientation of the energy metabolic profile towards conservation of carbohydrates, and intensification of lipolysis and stress their counter-regulating role in comparison to glucose. No possible relations were revealed between general energy consumption, changes in hormone and leptin levels in regulatory mechanisms. Thus it can be assumed that both the proposed effort (energy consumption) and its duration were hardly effective stimulus, sufficient to discover the role played by leptin in the afferent signalization for hypothalamic hunger centres, which additionally emphasizes the fact that energy balance in bodies of the exercising women was not disturbed.

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PHYSIOLOGICAL AND METABOLIC RESPONSES TO AQUATIC RESISTANCE TRAINING IN HEALTHY MEN: A COMPARISON BETWEEN LAND-BASED AND IN-WATER EXERCISES

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ABSTRACT

The objective of the study was to compare the responses in terms of heart rate (HR), plasma lactate concentrations (La^-) and blood pressure (BP) derived from the same resistance training exercise performed in water and on land. Eleven healthy male subjects aged 26.5 ± 5.2 (mean ± SD) were selected, with 3.9 ± 2.5 years of experience in resistance exercises. In-water exercise (WE) consisted of a horizontal abduction shoulder movement using resistance equipment (Hydro-Tone Bells). Land-based exercise (LE) was the chest cable cross-over. The subjects performed 15 maximum-effort repetitions (RPE of 9–10). Compared to the LE, the WE caused a greater elevation of (La^-) (1, 3, 5 min.), with minute 3 being significant ($p < 0.05$). The post-exercise heart rate (HRP) was greater following the LE ($p < 0.05$), without said difference being significant at 1, 3 and 5 min. compared to the WE. Both systolic BP (SBP) and diastolic BP (DBP) were somewhat higher following the LE than the WE, without being significant. Under the appropriate methodological and material conditions, the WE would appear to provide similar physiological and metabolic responses to the LE for the same work intensity in young men with experience in resistance training.

Key words**:** strength, exercise, aquatics, heart rate, lactic acid, blood pressure, fitness.

INTRODUCTION

Resistance training is among the physical activities that have witnessed the biggest increase in popularity in recent years. From health perspective, it presents new challenges that involve embracing different environments and equipment as a complement or reinforcement and/or in some cases as a viable alternative to the methodologies traditionally employed in resistance training. Of fitness-related activities and with regards to the number of participants, aquatics accounted for a very high percentage of the total in the late 1990s [20]. Over the last few years, there has been constant research into leisure-time aquatic fitness, looking at various population types and based on exercises not exclusive to swimming techniques [1, 10, 30, 33].

As for in-water resistance training, it is known to improve strength in the elderly [33], in people with pathologies [6, 12, 35], and in young, healthy and active subjects [22] and that it can bring significant increases in isometric and isokinetic strength followed by a proportional rise in neural activity and a significant increase in the muscular cross-section of the groups trained (lower body) [26]. Nevertheless, there remain some lacunae regarding the physiological repercussions of in-water resistance training.

In resistance training, the concentrations of lactic acid (La^-) are much higher during the concentric phase than during the eccentric phase [15, 16]. Heart rate (HR) increases in both the concentric and eccentric phases proportionally to the intensity of the exertion, but increase is much higher in the concentric phase [15]. Blood pressure (BP) is also a direct reflection of the intensity obtained and is clearly related to the effort made in this type of activity [9, 15, 19].

In-water resistance training activities almost exclusively involve concentric actions. Each repetition produces a sum of concentric actions, unlike exercises performed on land (concentric and eccentric) and therefore the (La^-), HR and BP responses can produce different values to the same exercises performed on land. The aim of this study is to compare the (La^-), HR and BP responses to the same upper-body resistance training exercise in water and on land in young, healthy male subject with experience of resistance training on land.

METHODS

Subjects

Eleven healthy male subjects were selected, whose characteristics are presented in Table 1, age 26.45 ± 5.2 (mean ± SD) years old, height 1.72 ± 0.03 metres, weight 73.89 ± 7.98 kg, body fat percentage 11.53 ± 1.28, body mass index 24.65 ± 1.99, resistance training experience 3.9 ± 2.5 years, average weekly training frequency 3.45 ± 0.93 days. The requirements to be part of the sample were a minimum of 1 year's recreational resistance training on land, not to participate in any sporting event and for their physical practices to have a clear methodological learning towards bodybuilding. The PAR-Q questionnaire (ACSM, 1998) was used to disqualify any kind of health problem that might hinder the subject's participation in the research. Those taking any type of anabolic steroid or over-the-counter ergogenic aid either at the time or during the year prior to the experimental process were also disqualified. All subjects were informed of the tests and measurements they were to undergo and gave their written consent.

Procedures

The study was conducted over one week and comprised two sessions: Session 1 at the beginning of the week and Session 2 72 hours later, to provide sufficient recovery time.

Session 1

All the subjects were convened at the same time of day, when they underwent an anthropometric assessment. All measurements were taken in a room with a constant temperature of 20 ± 1°C. The measurements were always taken by the same researcher, in line with the recommendations of the Spanish Kinanthropometry Group [8]. The selected parameters were: corporal dimensions (weight (kg), height (m) and body mass index (BMI = Kg/m^2)), using mechanical scales and a SECA height rod (SECA LTD, Germany) with a sensitivity of 100 grams and 1 millimetre respectively; and skinfold measurements: triceps, subscapular, supraspinal, abdominal, thigh and calf. A Holtain skinfold calliper (Holtain Ltd, UK) was used for these measurements. Diameters (bistyloid and bicondylar humerus and femur) were determined using a Holtain calliper (Holtain Ltd, UK) and circumferences (contracted arm, thigh and calf) were also measured in triplicate, using a nonflexible Holtain glass-fibre measuring tape marked in millimetres (Holtain Ltd, UK). The data were entered into the Medidep 2000 V2.4.139 software programme for Windows (SportSoft 2000). The subjects were allowed to practise the following exercises under supervision, so that the appropriate corrections could be made until they acquired the proper technique:

In-water exercise: horizontal abduction (HA)

The HA movement is a glenohumeral abduction to 80° in the scapular plane with an elbow flexion of 20° and without any movement from other body segments to help. A support point for one of the legs was permitted on the wall of the pool. The extent of the movement ranged from the hands being almost together in the horizontal adduction of the shoulder to a horizontal shoulder abduction of minus 20°, using the participant's frontal body plane as the point of reference in this instance.

Land-based exercise: chest cable cross-over (CCC)

Following the above technical execution instructions for the HA, this exercise was performed by the subjects standing on both feet at the Telju adjustable crossover pulley, with the pulleys at shoulder height so that the direction of the load was the same as for the in-water exercise. Back-foot support was also permitted.

Test to determine work intensities

The subjects were required to perform 15 maximum-effort repetitions (RPE 9–10 according to OMNI-RES by Robertson et al. [28]). The resistance equipment used for the WE were Hydro-Tone Bells (Aquatic Fitness Systems, Inc., Huntigron Beach, CA) or resistance boxes and the corresponding load in kg for the LE. The subjects had been previously instructed in the use of the OMNI-RES scale.

To determine the rate of execution, a duly protocolised warm-up was performed beforehand, which was used both for this part of the study and for the subsequent tests. Immediately following the warm-up, the in-water exercise was then performed. The degree of immersion for all of the in-water exercise tests was such that the water was at shoulder height. The water temperature was 28°C, room temperature 29°C and humidity 53%. The starting rate was 65 $b \cdot m^{-1}$ for the HA, with the first signal (the word "one") indicating the outwards phase of the exercise, and the second (the word "two") indicating the return phase. The pace was controlled via a recording of the Fast&Soft Metronome (Version 4.0) amplified using a conventional audio player (amplifying loudspeaker B800).

If, during the test, the subject did not complete the repetitions anticipated, did more, was unable to keep up with the pace or altered the performance technique, the exercise was stopped, a recovery time of five minutes was given and then a different pace was selected, varying the rate according to why the previous attempt had been aborted. The test was repeated for up to a maximum of three attempts. Likewise, the same procedure was followed on land, varying the weight of the load.

The subjects were given verbal encouragement to ensure the required level of effort. Once the pace of the water movement had been set, the subjects then performed at the same rate for the land-based test. To maintain the same intensity on land as in water, 1RM was first determined for the CCC exercise. A test was then carried out with a load at 60% of 1RM and at the pace established for the in-water exercises in order to reach muscular fatigue at the end of the 15 repetitions and with the same level of maximum effort as in the in-water exercises.

Session 2

After 72 hours, during which time the subjects performed no kind of physical activity, baseline HR, (La^-) and BP measurements were taken. Following the warm-up, the WE was performed, then the LE. Recovery time between exercises was a minimum of 20 minutes.

HR for each of the exercises was measured using an electronic Polar® heart rate monitor (© Polar Electro Ibérica), model Polar S610i™, which recorded and stored the HR in every 5 seconds. Recording of this information began 30 seconds prior to each exercise and ended 5 minutes after the completion thereof. These data were then processed using the Polar Precision Performance Analysis software, version 4.0. At the end of the in-water exercises, the working heart rate (WHR) in water was recorded, followed by the recovery HR at 1, 3 and 5 minutes out of the water. For the land-based exercises, all recordings were made on land.

The concentration of blood lactate was obtained via a blood sample from the earlobe. The baseline value and the values at 1, 3 and 5 minutes following both the WE and LE were determined using a portable lactate analyser (Lactate Pro, LT-1710, KDK Co., Ltd). It should also be noted that none of the subjects performed any kind of intense eccentric work during the 72 hours prior to the testing. All samples were taken on the poolside and by the same person.

BP was measured using the WS-520 NISSEI Nihon Seimitsu Sokki Co., LTD digital blood pressure monitor, which had been previously calibrated and whose structural characteristics regarding maximum temperature (40ºC) and relative humidity (85%) permitted its use in the swimming pool. BP measurements were taken at rest and following the performance of each exercise and in duplicate with a separation interval of 72 hours (Sessions 1 and 2). All recordings were made by the same person, in the same place and within the same timeframe. All movements, situations of psychological tension, environmental changes and changes in temperature were avoided during the taking of the measurements and nor were the subjects allowed to talk and/or have ingested alcohol, tobacco or coffee. For the protocol, the manufacturer's specifications for use were followed, except that in this study the subject was standing, both on land and in water. In the aquatic environment, the baseline reading was taken once the subject had been in the water for at least 5 minutes. The post-exercise measurement was taken in the water and with the left arm supported on the poolside (out of the water) and at the same height relative to the body as on land. The skin was dried where the blood pressure monitor was to be placed and then the reading was taken.

Statistical analysis

Using the Statistical Package for Social Sciences (SPSS) v. 14.0 programme, a test was initially carried out for normality and homogeneity of variance. The descriptive statistics were then analysed and the Student T test for independent samples was finally applied. Significance was set at $p < 0.05$.

RESULTS

Table 1 shows the data relating to the anthropometric assessment of the subjects.

Table 1. Baseline characteristics of subjects.

n=11	mean ± SD
Age (years)	26.4±5.2
Weight (kg)	73.89±7.98
Height (m)	1.72±0.03
BMI ($kg{\cdot}m^{-2}$)	24.65±1.99
Body Fat (%)	11.53±1.28
Experience (years)	3.9±2.5
TF ($times{\cdot}wk^{-1}$)	3.45±0.93
SM ($b{\cdot}min^{-1}$)	78.81±5.75
Load (kg)	22.72±2.61

BMI = body mass index
TF = training frequency
SM = speed of movement

Figures 1 and 2 show the concentration values of blood lactate in the in-water exercise and in the land-based exercise. At Minute 1, both exercises show an increase ($p \leq 0.01$) in (La^-) concentrations in relation to the baseline figures, displaying significant differences between the WE and the LE at minute 3 (5.28 ± 1.1 and 4.11 ± 0.5 respectively; $p \leq 0.05$) and somewhat higher but not significantly different at minutes 1 and 5 (4.07 ± 1.43 and 3.7 ± 0.69; 4.93 ± 0.89 and 4.19 ± 0.62).

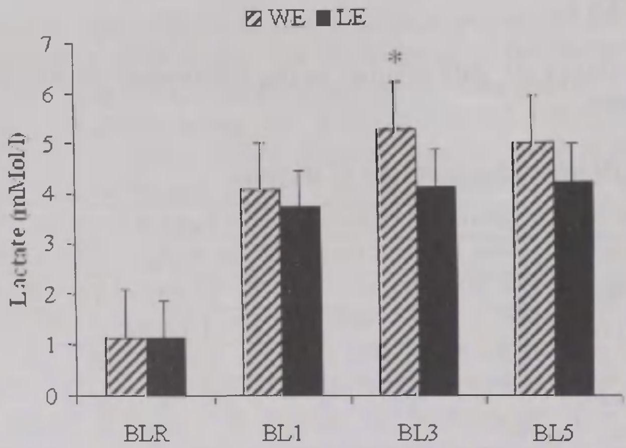

Figure 1. $*p \le 0.05$
WE = in-water exercise, LE = land-based exercise, BLR = blood lactate at rest. BL1, 3, 5 = blood lactate 1 min, 3 min, 5 min.

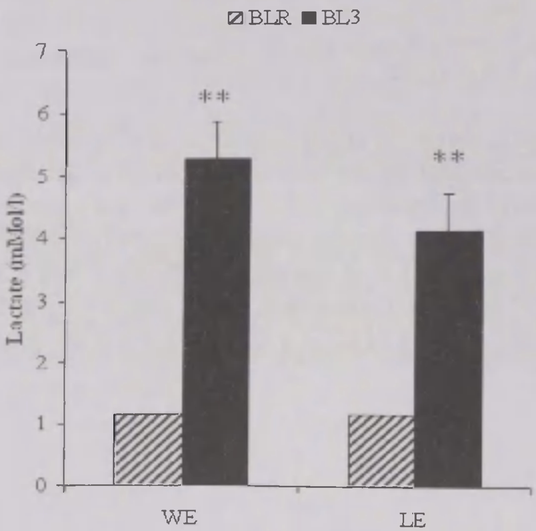

Figure 2. $**p \le 0.01$
BLR = lactate at rest. BL3 = blood lactate 3 min. WE = in-water exercise. LE = land-based exercise.

Figures 3 and 4 show the HR values for the in-water and land-based exercises. The heart rate post-exercise (HRP) was higher ($p \leq 0.01$) than the HRR in both exercises. The HR rose more in the LE than in the WE (145.18 ± 10.88 and 132 ± 11.57; $p \leq 0.05$), remaining higher at minutes 1, 3 and 5 but without the difference becoming significant (94.18 ± 9.02 and 87.64 ± 8.46; 72.36 ± 7.92 and 70.45 ± 10.40; 72.27 ± 6.51 and 66.73 ± 7.10).

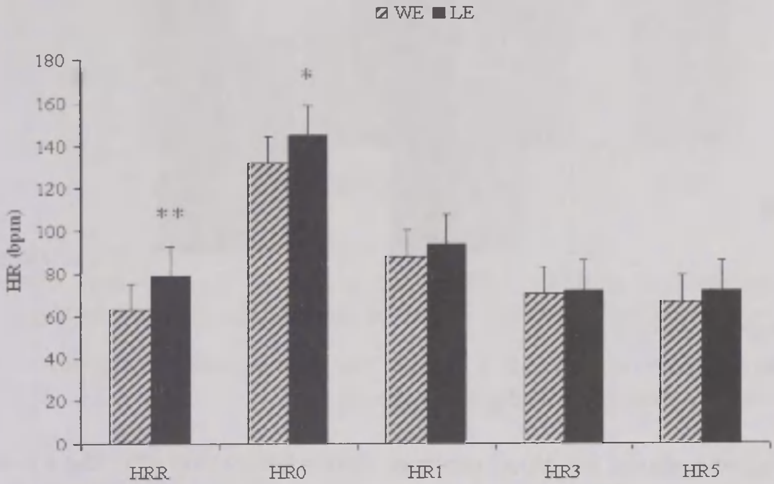

Figure 3. *$p \leq 0{,}05$
**$p \leq 0{,}01$
WE = in-water exercise. LE = land-based exercise. HRR = heart rate rest. HR0, 1, 3, 5 = heart rate 0 min, 1 min, 3 min, 5 min.

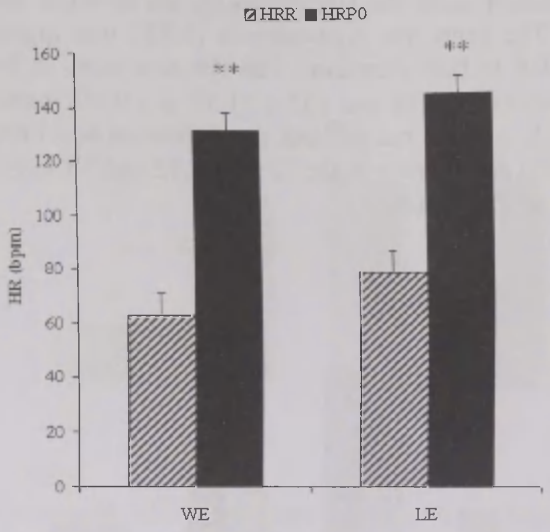

Figure 4. **$p \leq 0{,}01$
HRR= heart rate rest. HR0 = heart rate post-exercise 0 min. WE = in-water exercise. LE = land-based exercise.

Figure 5 shows the blood pressure values before and after the LE and the WE. The SBPR was lower in water than on land (116.09 ± 7.55 and 128 ± 8.50; $p \leq 0.01$). Figures 6 and 7 show that the WE produced a significant rise in SBP (116.09 ± 7.55 and 131 ± 10.51; $p \leq 0.01$) over the SBPR. However, SBP following the LE proved somewhat higher than following the WE (133.73 ± 9.27) but without showing any major differences.

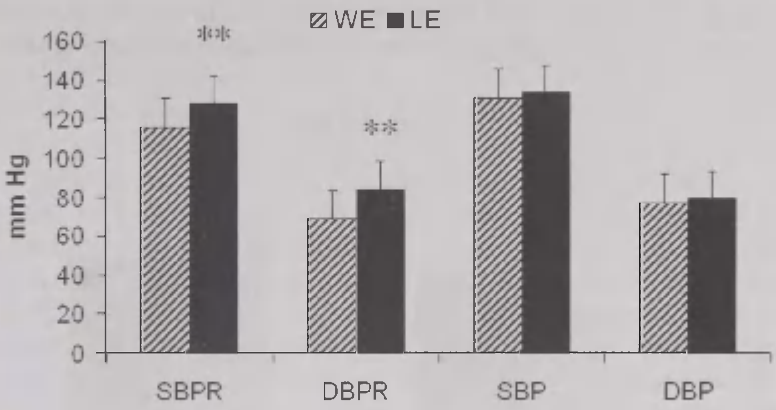

Figure 5. $^{**}p \leq 0.01$
SBPR = systolic blood pressure at rest. DBPR = diastolic blood pressure at rest. SBP = systolic blood pressure. DBP = diastolic blood pressure.

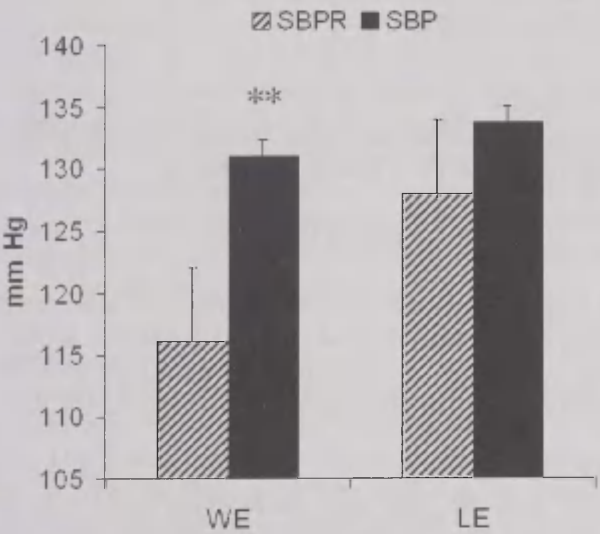

Figure 6. $^{**}p \leq 0.01$
SBPR = systolic blood pressure at rest. SBP = systolic blood pressure. WE = in-water exercise. LE = land-based exercise.

Post-exercise DBP was higher than DBPR ($p \leq 0.01$). The WE raised the DBP considerably over the DBPR (68.55 ± 4.36 and 76.73 ± 6.91; $p \leq 0.01$), with little difference between the two exercises (Figures 6 and 7).

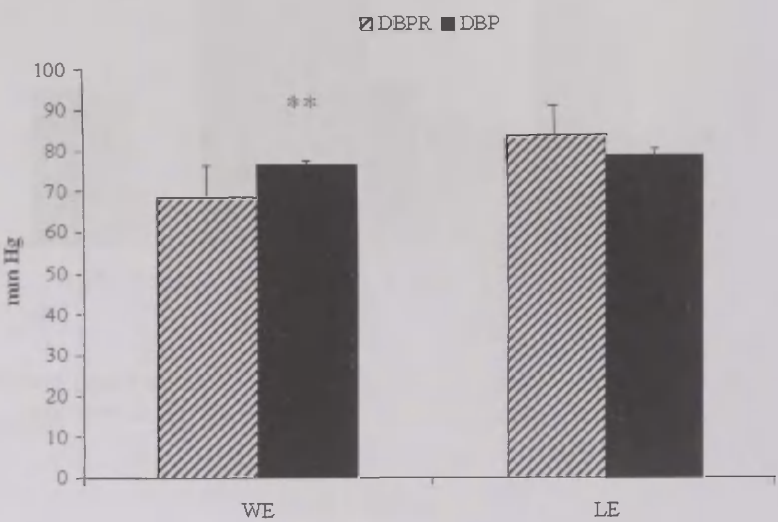

Figure 7. **$p < 0.01$
DEPR = diastolic blood pressure atrest. DBP = diastolic blood pressure. WE = in-water exercise. LE = land-based exercise.

DISCUSSION

The (La^-) concentration, HR and BP levels are values enabling the quantification of the effort derived from the resistance exercises, since they directly reflect the intensity obtained during these activities and more markedly during the concentric actions [15, 16, 18, 39].

Heart Rate

In this study, both the HRR and the recovery heart rate (RHR) are lower in the WE than in the LE. Other studies have also found reductions in HR [3, 17, 30, 32]. Butts et al. [2] found that maximum HR was on average 17.6 beats/minute lower during deep-water running than during treadmill running. Frangolias et al. [11] provide similar reductions in maximum HR (15 beats/minute) during aerobic exercises.

In our study, the WE produces a highly significant rise in HRP over HRR, as also occurs during the LE. However, although the HRP obtained following the LE is higher, the WE raises HRP over HRR 6.77% higher (WE 52.35% vs LE 45.58%). If HR rises in proportion to the intensity of effort [15], this datum shows that the effort on the WE has been highly significant, even proportionally higher than on the LE. This may be attributed to the fact that the WE involve the sum of concentric action, with concentric actions in a higher proportion than those provided by the LE, where the movement would comprise concentric and eccentric actions. It is also worth noting those actions derived from the fixed musculature, which take on a special role due to the unstable characteristics of the aquatic environment as suggested by Sova [31] and Sanders [29]. In any case, the final HR result is lower for the WE than for the LE and for aerobic exercises.

Sheldahl et al. [30] indicate that the differences in physiological responses between the WE and the LE do not alter the cardiovascular adaptations to exercise in the aquatic environment. This fact is supported by various studies [1, 7, 27, 33, 34, 38] that confirm aerobic improvement through in-water exercises. Likewise, the lower HR responses following in-water resistance exercises may not be a limiting factor for adaptations in strength, hypertrophy and in increases in cross-section area, as there are several studies confirming this [22, 26, 33]. In-water resistance training gives a lower HR than land-based exercises at similar intensities, and therefore HR is a difficult variable to use for comparing the intensities derived from in-water resistance exercises with their land-based counterparts.

Blood Lactate

Land-based studies have used plasma lactate concentrations with the aim of quantitatively evaluating the effort derived from resistance training [15, 16]. It was observed that lactate levels increased proportionately with the intensity of effort, verifying the direct relationship that exists between the two parameters and even coming to prove that, for high intensities, lactate level remained high for several minutes. It has also been shown that the concentrations deriving from the concentric phase were much higher (statistically significant ($p < 0.05$)) than from the eccentric phase.

The fact that during the WE the sum of two concentric actions are produced throughout a repetition could be the reason why our studies showed higher values than for the LE (3.508% higher at minute 1 and 8.022% at minute 3). These data suggest that the effort in the WE was quantitatively greater than in the LE, confirming that it is feasible to set significant work intensities for in-water resistance exercises in healthy populations experienced in resistance training. Nevertheless, it should also be appreciated that the WE involved more muscle groups than the LE, which might also explain the values obtained following the WE.

In the aquatic environment, studies have been made of (La^-) concentrations following cycloergometric and aquarunning exercises at various intensities. Works such as those by Svedenhag et al. [32], Glass et al. [13] and Chu et al. [4] indicate that a higher concentration of (La^-) is produced in the WE as opposed to in the LE. These increases are produced as the consequence of an increase in anaerobic metabolism that could be due to lower perfusion pressure in the lower extremities as a result of abnormal blood flow arising from: hydrostatic pressure; the synergy of other muscle groups that do not come into play on land, or that do so to a lesser degree; muscular activation being maintained for a longer duration during the performance of the exercise; and/or from a possible alteration to exercise technique that involves a modification to muscular activation patterns [4].

Following the same line of argument but from an opposite stance, Frangolias et al. [10], Town et al. [36] and Benelli et al. [1] observed that (La^-) concentrations are lower for aerobic exercises performed in water than those obtained on land. Specifically, Connelly et al. [5] observed that maximum-immersion exercises caused lower levels of (La^-) and that although plasmatic adrenaline (epinephrine) and noradrenaline (norepinephrine) are present during the exercise, they found lower concentrations of noradrenaline at between 78 and 82% VO_2max, while the plasmatic adrenaline values were lower only in maximum efforts during the immersed exercises. The lower levels of adrenaline in plasma observed during a maximum effort could generate a reduction in glucogenolysis and consequently in the concentration of muscular (La^-). As a possible explanation for this circumstance, these authors also propose the idea that muscular blood flow increases in water, increasing aerobic metabolism and consequently reducing (La^-), resulting in lower levels of plasmatic adrenaline. Connelly et al. [5] believed that the elimination of adrenaline and lactate is increased during maximum exercise and that the plasmatic responses of catecholamines are altered upon immersion in water.

It is difficult to discern whether the drop in noradrenaline is the result of a reduction in sympathoadrenal activity, due to increased elimination of adrenaline or instead to an alteration in the metabolic response to the exercise [10]. These discrepancies in the variability of the results could be due to the differences within the studies when it comes to proposing the experimental designs with regards to water temperature, level of immersion, performance rate, muscle groups involved and the degree of familiarity with the technique of the proposed exercise [1, 4].

The results of the current study may help towards a better understanding of the effects of immersion on (La^-) concentrations in WE. Results indicate higher levels post-WE, leading to the interpretation that immersion has produced no negative effects on (La^-) concentrations for this type of exercise and that the fluctuations previously cited could therefore be due, as suggested by Frangolias et al. [10], Chu et al. [4] and Benelli et al. [1], to possible alterations in methodology, which in turn cause variations in the metabolic responses to the exercise.

(La^-) does not appear to be that influenced by the individual characteristics of the aquatic environment and, given that it is a clear indicator of the intensities derived from typically anaerobic exercises such as resistance training, it could enable said comparison to be established between the WE and the LE. The concentrations of (La^-) are found to be similar for both exercises, even becoming somewhat higher following the WE. The reason for this difference is perhaps also due in this case to variations with regards to the type of muscular actions used for each of the environments. Future studies should observe the plasmatic responses of catecholamines for in-water resistance training exercises in order to support this theory.

Blood Pressure

During the performance of the resistance training exercises on land, there are changes at cardiovascular level that increase systolic blood pressure (SBP), diastolic blood pressure (DBP) and mean blood pressure (MBP) [14, 18, 21, 39]. There are linear increases in SBP in relation to the workload [19, 40].

Both Miwa et al. [23] and Park et al. [25] found no significant changes in blood pressure when immersing young, healthy subjects in water. In contrast, Ward et al. [37] observed a significant drop in blood pressure upon immersion in water (MBP mean difference of 10.52 mm Hg), returning to these levels once the exercise had been performed and remaining there while immersed, to return to pre-immersion values 8–12 minutes after leaving the water. Zukowska-Szczechowska et al. [41] also observed this drop in persons with renal pathologies, and Nishimura et al. [24] in young and healthy subjects in supine flotation.

In our study, we also observed a drop in mean blood pressure rest (MBPR) (14.27 mm Hg between the WE and the LE) and in the baseline levels for both SBP and DBP (Figures 6 and 7). No data have been found regarding blood pressure for in-water resistance training exercises. For aerobic exercises, there are studies showing little variation in systolic blood pressure both at baseline and during exercise as compared to the values obtained on land [3]. On the other hand, Sheldahl et al. [30] observed a drop in SBP and DBP for the same exercise (cycling) and intensity.

It would appear that, just as with HR, the cardiovascular changes that the subject undergoes in BP upon immersion in water are the main factors responsible for a lower end product and make BP a difficult variable to use for establishing an adequate comparison of intensity between the two environments. The WE raised SBP over SBPR 7.63% higher than the LE (11.39% WE vs 3.76% LE) (Figure 6). Likewise, DBP was significantly higher than DBPR in the WE and in the LE. The DBPR was 18.41% lower in the WE than in the LE, so that although the DBP was 2.99% higher in the LE than in the WE, the WE saw it rise over DBPR 16.5% higher than the LE (Figure 7). A possible explanation for this circumstance could be the sum of concentric actions caused by the WE.

The results of this study can help improve knowledge of the mechanisms, responses and potential adaptations deriving from water bodybuilding practices and thereby offer a safe and appropriate prescription to individual and personal requirements within the different fields of application (recreation, rehabilitation, sporting performance, etc.) currently requiring and/or demanding it.

CONCLUSIONS

The WE caused a greater rise in (La^-), a lower rise in HR and a similar increase in BP with regard to the LE, enabling us to conclude that:

1. The in-water exercise created a similar work intensity to the land-based exercise.
2. Both heart rate and blood pressure are difficult variables to use for comparing intensities in the two environments.
3. The peak concentration of lactic acid appears to be a variable capable of enabling the comparison of intensities in the two environments.
4. The in-water resistance training exercise produces a lower heart-rate and blood-pressure response than the land-based exercise in young, healthy and trained subjects at the same work intensity.
5. In-water resistance training could be an effective alternative for developing strength in young and healthy people.

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PROFILING OF PHYSICAL FITNESS OF MALAYSIAN RECREATIONAL ADOLESCENT TAEKWONDO PRACTIONERS

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ABSTRACT

The purpose of this study was to assess and compare the physical fitness of adolescent recreational taekwondo athletes. Subjects were recruited from the northeast of Peninsular Malaysia (8 males, 17.30 ± 1.90 years, 166.81 ± 5.97 cm, 56.38 ± 7.69 kg, and 8 females, 17.35 ± 1.86 years, 157.70 ± 4.82 cm, 52.40 ± 5.81 kg). Body composition, hip flexion of the straight and bent dominant kicking leg, explosive leg power, aerobic fitness and maximum exercise heart rate (HR_{ex}) were measured. In absolute terms, the boys (35.63 ± 4.10 cm) jumped higher than the girls (26.00 ± 3.55 cm, $p < 0.001$, $eta^2 = 0.643$). The difference became smaller when jump height was scaled to height^2 (12.79 ± 1.19 cm/m^2 and 10.45 ± 1.33 cm/m^2 for the boys and girls, respectively, $p = 0.002$, $eta^2 = 0.497$). The boys also had greater aerobic endurance (49.03 ± 3.87 ml.kg^{-1}.min^{-1} vs. 39.54 ± 2.77 ml.kg^{-1}.min^{-1}, $p < 0.001$, $eta^2 = 0.760$). The difference persisted when height was used as a co-variate (48.40 ± 4.03 ml.kg^{-1}.min^{-1} for the boys and 40.17 ± 4.03 ml.kg^{-1}.min^{-1} for the girls, $p = 0.001$, $eta^2 = 0.603$). As expected, sexual dimorphism in physical fitness was found in recreationally active adolescent athletes.

Key words: physical fitness taekwondo

INTRODUCTION

With the inclusion of taekwondo as an official sport in the 2000 Sydney Olympic Games, research on this sport has increased in recent years. Most of these studies were carried out on adults. For instance, Toskovic et al. [27] investigated the acute cardiovascular and metabolic effects elicited during a dynamic taekwondo exercise and assessed whether it provided adequate cardiorespiratory demands to enhance aerobic fitness. Dynamic taekwondo performance resulted in significant increases in exercise heart rates for effective initiation of cardiovascular adaptations and conditioning. The mean heart rate responses (88.3–92.2% of maximal heart rate) were well above the threshold (60%) for a cardiovascular training effect.

In a follow-up study, Toskovic et al. [26] revealed that, collapsed over gender, more experienced recreational taekwondo athletes to have lower body fat and higher aerobic fitness than their less experienced counterparts. Heller et al. [11] reported that the successful taekwondo competitor tended to demonstrate low levels of body fat and elevated aerobic fitness and flexibility. Bouhlel et al. [4] also arrived at the conclusion that elite taekwondo athletes may be characterized by low fat and well-developed aerobic endurance.

Markovic et al. [17] investigated physical fitness and motor abilities in female Croatian elite taekwondo athletes with the purpose of distinguishing between successful and less successful counterparts. The successful athletes had higher explosive leg power, aerobic endurance and lateral agility.

Heller et al. [11] reported that elite Czech male and female taekwondo athletes recorded 36.9 cm and 37.9 cm, respectively, on the sit-and-reach test. Vertical jump measured on a Kistler force platform was 45.4 cm and 29.8 cm for males and females, respectively. In American recreational taekwondo athletes there was no experience effect relative to explosive leg power but there was for taekwondo-specific flexibility, i.e., lateral splits, with the more experienced practitioners performing better [26].

Few studies were conducted on young taekwondo practitioners. Cetin et al. [5] developed a regression equation to determine aerobic endurance in 16-year old Turkish boys and girls. Bercades et al. [2] reported maturity and gender effects for average anaerobic power in American 14-year old national competitive taekwondo athletes.

Collapsed over gender the prepubertal children had lower average power, while the boys recorded higher values than the girls.

Skill-related fitness research on taekwondo in Malaysia is scarce. Our own team investigated physical fitness in national adolescent taekwondo athletes. There were no differences between adolescent winners and losers within gender in explosive leg power and aerobic fitness [29]. Suzana and Pieter [23] reported young national taekwondo athletes to improve in motor abilities after an intervention. Collapsed over gender, sit-and-reach flexibility improved over time. However, the boys had greater explosive leg power than the girls, even after allometric scaling for body mass with an empirically derived exponent. The purpose of this study, then, was to assess and compare the physical fitness of Malaysian adolescent recreationally competitive athletes.

METHODS

Subjects were recruited from the northeast of Peninsular Malaysia (8 males, 17.30 ± 1.90 years, 166.81 ± 5.97 cm, 56.38 ± 7.69 kg, and 8 females, 17.35 ± 1.86 years, 157.70 ± 4.82 cm, 52.40 ± 5.81 kg). Body composition was assessed using the regression equation developed for Singaporean Malays, Chinese and Indians [8]. Hip flexion with the straight and bent dominant kicking leg was assessed with a Leighton flexometer (Leighton Flexometer, Inc, Spokane, WA, USA). The counter-movement vertical jump (CMJ) was used to assess explosive power of the legs. However, no attempt was made to control for the angle of the knees when lowering the body before the jump as suggested by Domire and Challis [9]. The subjects were allowed three jumps with a 1-minute rest in between jumps. The highest jump was used for statistical analysis.

Aerobic fitness was estimated by means of the 20 m multi-stage fitness test [21]. The test was terminated when the participants could no longer keep up with the set pace and failed to reach the turning line on two consecutive occasions [14]. Maximum exercise heart rate (HR_{ex}) was measured using a Polar watch (Polar Electro Oy, Kempele, Finland).

Data distributional characteristics were assessed for skewness and kurtosis, while the Kolmogorov-Smirnov test was employed to verify normality. The L-statistic was used if the statistical assumptions could not be met, even after data transformation [24]. An independent t-test was used to determine the differences between boys and girls in physical fitness. To partition out the independent influence of height on aerobic endurance it was entered as a co-variate in a one-way analysis of co-variance (ANCOVA) [28].

Allometric scaling was employed to compare boys and girls in explosive power relative to height^2 and LBM$^{0.67}$ [1, 15]. The level of significance was set at 0.05. Since the interest in this study was not in the universal null hypothesis, it was decided not to adjust the error rate for multiple comparisons [20].

RESULTS

Table 1 displays the means and standard deviations for the bio-demographic data and the fitness components. The boys were taller ($p = 0.002$, $eta^2 = 0.517$) and also had more lean mass ($p < 0.001$, $eta^2 = 0.594$).

Table 1. Descriptive statistics of demographic data and fitness variables

Variables	Boys	Girls
Age (years)	17.30±1.90	17.35±1.86
Height (cm)	166.81±5.97	157.70±4.82
Mass (kg)	56.38±7.69	52.40±5.81
Fat (%)	19.58±2.65	31.13±2.57
LBM (kg)	45.18±4.90	35.98±3.02
Hip flexion – bent leg (°)	118.25±8.21	123.88±5.77
Hip flexion – straight leg (°)	102.75±10.20	107.75±10.51
CMJ (cm)	35.63±4.10	26.00±3.55
Sub-max VO_2 ($kg.ml^{-1}.min^{-1}$)	49.03±3.87	39.54±2.77
HR_{ex} ($beats.min^{-1}$)	188.88±4.94	182.75±4.77

In absolute terms, the boys jumped higher than the girls ($p < 0.001$, $eta^2 = 0.643$). The difference became smaller when jump height was scaled to height^2 (12.79 ± 1.19 cm/m^2 and 10.45 ± 1.33 cm/m^2 for the boys and girls, respectively, $p = 0.002$, $eta^2 = 0.497$). The effect of the body size variable on jump height was adequately controlled by allometric scaling using the theoretical exponent: ($r = 0.14$, $p = 0.737$ for the boys and $r = 0.09$, $p = 0.833$ for the girls).

When expressed relative to $LBM^{0.67}$, the difference between boys and girls decreased further as compared with scaling the jump to height^2: 2.79 ± 0.35 cm/kg$^{0.67}$ versus 2.37 ± 0.42 cm/kg$^{0.67}$, respectively ($p = 0.051$, $eta^2 = 0.246$). The effect of the body size variable on jump height was adequately controlled using allometric scaling with the theoretical exponent for LBM: $r = -0.43$ for the boys ($p = 0.291$) and $r = -0.67$ for the girls ($p = 0.070$).

The boys had greater aerobic endurance ($p < 0.001$, $eta^2 = 0.760$). The difference decreased when height was used as a co-variate: 48.40 ± 4.03 $ml.kg^{-1}.min^{-1}$ for the boys and 40.17 ± 4.03 $ml.kg^{-1}.min^{-1}$ for the girls ($p = 0.001$, $eta^2 = 0.603$). Exercise heart rate for the boys was higher than for the girls ($p = 0.024$, $eta^2 = 0.312$).

DISCUSSION

Athletes were tested mainly on joints of the body that are most involved in kicking, especially the roundhouse and axe kicks. Although the ability to move joints through their full range of motion is considered an important asset in many sports, information is lacking regarding sport-specific flexibility [12]. In taekwondo, lower limb flexibility will allow the athlete to kick higher, which may result in scoring more points, since kicks to the head are worth more points compared to other parts of the body that are legitimate target areas.

Male Filipino national silat athletes scored 123.9° for hip flexion with a straight leg and their female counterparts, 124.6°, while Filipino national karate athletes recorded 109.8° and 130.2° for males and females, respectively [3]. Ranges of motion for non-athletic subjects were reported to be 121.3°–123.4° for hip flexion with the leg bent at the knee joint and 77.5°–105.0° with the leg straight [12]. Neither the gender, nor the age of these subjects was disclosed, however.

Previous studies on martial arts used the sit-and-reach test to assess flexibility. For instance, Toskovic et al. [26] reported values of 31.7 cm (novice males), 39.1 cm (experienced males), 37.0 cm (novice females), and 35.9 cm (experienced females) for American recreational taekwondo athletes. Markovic et al. [17] found 55.8 cm for the total group of elite Croatian female taekwondo athletes.

Comparative data for explosive leg power in martial arts athletes are displayed in Table 2. Yugoslavian young female karate athletes (12–13 years) reached a vertical jump height of 27.4 cm. Their younger male counterparts (10–11 years) recorded vertical jumps of 24.9 cm and 23.1 cm, respectively [13]. American recreational taekwondo athletes recorded CMJ heights of 43.7 cm (novice males), 51.5 cm (experienced males), 32.1 cm (novice females), and 31.3 cm (experienced females) [27].

Table 2. Absolute vertical jump height (cm) in taekwondo and karate athletes

	Males	Females
Malaysian recreational taekwondo athletes (this study)	35.6	26.0
Malaysian national junior taekwondo athletes [3]	56.1	36.1
Czech international taekwondo athletes [11]	45.4	29.8
Filipino varsity taekwondo athletes (W. Pieter, unpublished data)	41.0	33.0
Croatian elite taekwondo athletes [17]	–	30.6
Belgian elite karate athletes [7]	54.8	–

Although both theoretical exponents sufficiently accounted for the removal of the effect of the body size variable on the vertical jump, scaling for lean mass decreased the difference between boys and girls more than using height as the scaling factor. However, the theoretical exponent of 0.67 for lean mass in this small sample, may not have adequately removed the effect of the body size variable on vertical jump height. In other words, allometric scaling failed to produce a dimensionless physiological performance variable [28].

It was also found that strength increased at a greater rate to height than predicted by geometric similarity theory [15, 22], while others have suggested that humans, both athletic and sedentary, may not be geometrically similar in strength [19]. Future studies should also investigate the effect of body size with empirically derived exponents on jump height [16] as well as using segmental lean mass instead of whole body lean mass [10, 28].

Table 3 displays comparative data on aerobic endurance in taekwondo athletes from various countries, who were assessed using the 20 m MSFT. The male British club athletes had a similar aerobic fitness as American recreational taekwondo practitioners assessed on a treadmill (44.0 $ml.kg^{-1}.min^{-1}$) [25]. Differences in training frequency and intensity may have contributed to the variation in aerobic endurance.

Table 3. Aerobic endurance ($ml.kg^{-1}.min^{-1}$) of taekwondo athletes

	Males	Females
This study	49.0	39.5
Malaysian Games athletes [29]	48.8	37.9
Filipino varsity athletes (W. Pieter, unpublished data)	35.8	37.3
British club athletes [6]	46.5	35.6

In the current study, when the effect of height was accounted for, the difference in aerobic fitness between males and females decreased but was still moderate. Since the exercise heart rate of the girls was lower, they may not have given an all-out effort. Chan and Pieter [6] found no difference in height-adjusted aerobic fitness between British recreational taekwondo athletes: 44.0 $ml.kg^{-1}.min^{-1}$ and 38.0 $ml.kg^{-1}.min^{-1}$ for males and females, respectively.

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PECULIARITIES OF PRESYNAPTIC INHIBITION OF IA GROUP AFFERENT FIBERS IN PERSONS OF DIFFERENT AGES

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ABSTRACT

The aim of our study was to assess age-specific peculiarities of the afferent la provision of human skeletal muscles (using the example of m. rectus femoris and m. soleus).

The experiment was conducted on 50 males aged 9 to 27 years (9–12 year-old boys, 14–15 and 17–18 year-old teenagers, and 22–27 year-old men).

The following methods were used to evaluate various afferent inputs in the process of ontogenesis: (1) the assessment of the presynaptic inhibition (PI) of heteronymous la afferent fibers of m. soleus going from m. rectus femoris to the m. soleus α-motoneurons [2] and (2) recording of the m. soleus la afferent fiber PI under homonymous vibration stimulation of tendo calcaneus.

It was concluded that the change of intensity of the presynaptic inhibition of the m. rectus femoris la afferent fibers and m. soleus primary afferent fibers, both under heteronymous conditioning electric stimulation and homonymous vibration stimulation, is caused by the development of reflectory functions of the neuromotor apparatus, which is associated with the level of the morphofunctional maturation of its links and their anatomic changes in the process of the human age-related development.

Key words: presynaptic inhibition, age

INTRODUCTION

Currently, notions about age-specific peculiarities of excitation processes in various organs and systems of the human body have been formed [3, 6, 8, 9, 10, 11]. Inhibition processes taking place in various structures of the human central nervous system in the process of ontogenesis are less investigated. However, latest electroneuromyography methods make it possible to study various inhibition processes in the human segmental apparatus, which was reflected in neurophysiological researches [1, 2, 5].

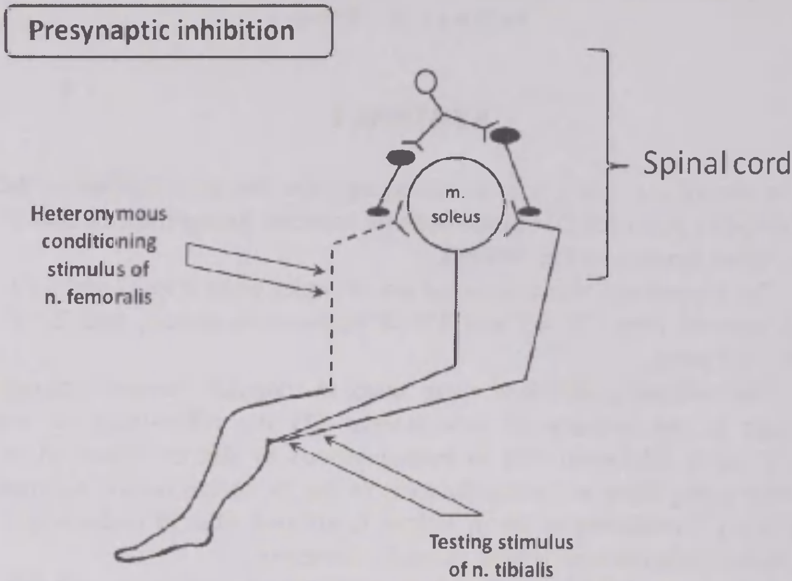

Figure 1. Method of determining presynaptic inhibition of heteronymous Ia fibers.

Notes:

——— – *m. soleus H-reflex path*

- - - - – *conditioning Ia flows from heteronymous n. femoralis*

The method of assessment of the presynaptic inhibition (PI) of heteronymous Ia afferent fibers of m. soleus going from m. rectus femoris to the m. soleus α-motoneurons [2] consists in the measurement of m. soleus H-reflex reinforcement caused by the conditioning stimulation of n. femoralis. During 0.5 ms, no non-monosynaptic influences affect the reinforcement of afferent flows through monosynaptic la fibers [2]. Under these conditions, the m. soleus H-reflex reinforcement depends on the conditioning excitatory postsynaptic potential value. Therefore, the more the m. soleus H-reflex reinforcement, the less the PI of the human skeletal muscle Ia afferent fibers.

Surface electrodes were used for the stimulation of n. tibialis and n. femoralis. 1 ms rectangular pulses from the Mini Electrostimulator were used as the stimuli. For surface EMG recording, pairs of non-polarizable disc electrodes with a diameter of 0.9 cm were used. The electrodes were placed at the distal one third of m. soleus and the straight line of the head of m. rectus femoris, 1 cm apart from each other.

The m. soleus H-reflex was invoked using the common method, by stimulating n. femoraiis through a unipolar electrode, the active electrode being placed in the popliteal space. The stimulation of n. femoraiis before the testing stimulus of n. tibialis was performed using unipolar electrodes. The active electrode was placed in trigonum femorale (Figure 1).

Under heteronymous conditioning stimulation, due to more proximal position of the electrodes used for the n. tibialis stimulation relative to the electrodes stimulating n. femoralis, the testing stimulus was applied before the conditioning stimulus. In this case, the interval between the conditioning stimulus and the testing stimulus had a negative value.

The vibration stimulation method of determination of PI of the m. soleus la afferent fibers, under homonymous vibration stimulation of tendo calcaneus, is based on the evaluation of m. soleus H-reflex amplitude suppression and its recovery in the aftereffect period. The more the m. soleus H-reflex suppression, the higher the PI of the n. tibialis la afferent fibers.

The persons being tested laid down on a special couch, in the back-lying position, with their legs outstretched and their feet drooping freely over the couch edge. A DC vibrator motor DMP-30-H1-01 with an eccentric (St. Petersburg, Russia, 2003) was used. The vibrator was attached to the right shin above t. calcaneus with a special rubber band. Moderate vibration was applied, for selective activation of the la afferent fibers of m. soleus. The stimulation frequency was 65 Hz, the oscillation amplitude was 0.25 mm irrespective of the vibrator pressing force (Figure 2).

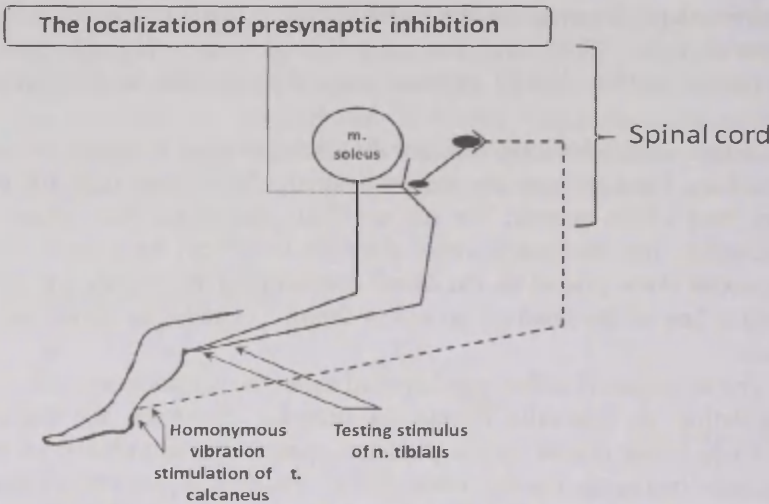

Figure 2. Vibration stimulation method of determining presynaptic inhibition of la fibers.

Notes:

——— *– m. soleus H-reflex path*

\- - - - *– conditioning Ia flows from heteronymous n. femoralis*

The m. soleus H-reflex was recorded during a 60-s period before the vibration stimulation, during a 30-s period of vibration stimulation, and during a 60-s aftereffect period. The interval between the testing stimuli applied to n. tibialis was 10-s.

The m. soleus biopotentials were taken using bipolar electrodes. Signals from the biopotential amplifier output were supplied through an analog-to-digital converter to one of the PC ports. For processing, the Myo software (ANO Vozvrascheniye, St. Petersburg, Russia) was used.

Data are means and standard errors (± SE).

RESULTS

As a result of the experiments, the most effective time intervals for recording the presynaptic inhibition of the m. rectus femoris Ia afferent fibers between heteronymous conditioning stimulation of n. femoralis and a testing stimulus of n. tibialis in different age groups were revealed. For 9–12 year-old boys and 14–15 year-old teenagers, the optimal delay values are –5.9; –5.3; –5.1; –4.9; –4.7 ms; for 17–18 year-old teenagers and 22–27 year-old men, the optimal delay values are –5.9; –5.7; –5.5 ms (Figures 3–5).

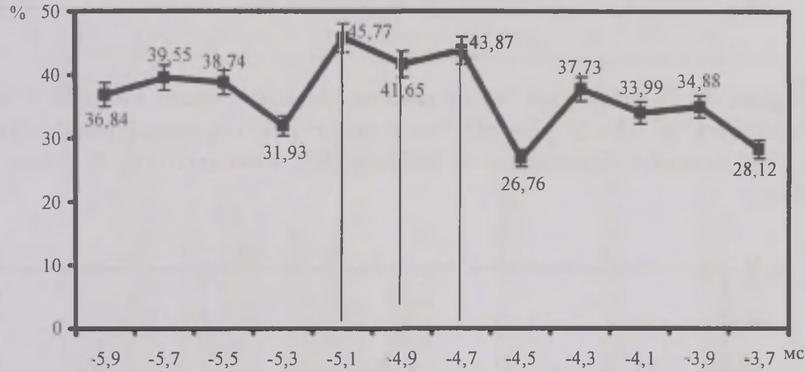

Figure 3. Dynamics of heteronymous m. soleus H-reflex reinforcement in 9–12 year-old boys under heteronymous conditioning stimulation of n. femoralis, with different delays between stimuli (mean ± SE).

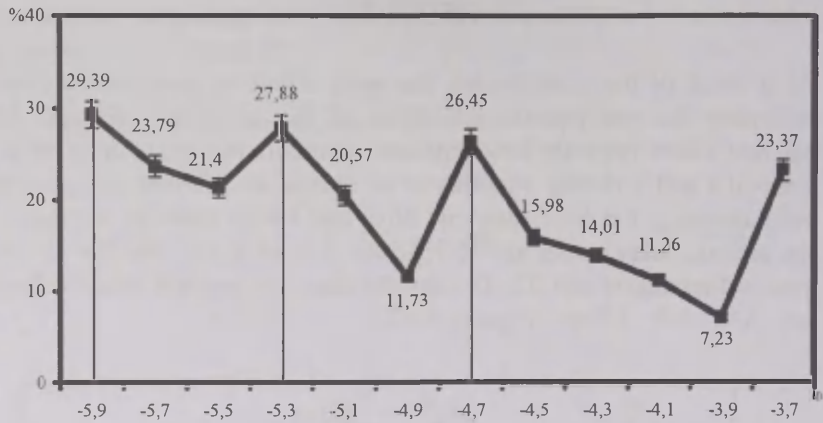

Figure 4. Dynamics (in %) of heteronymous m. soleus H-reflex reinforcement in 14–15 year-old boys under heteronymous conditioning stimulation of n. femoralis, with different delays between stimuli (mean ± SE).

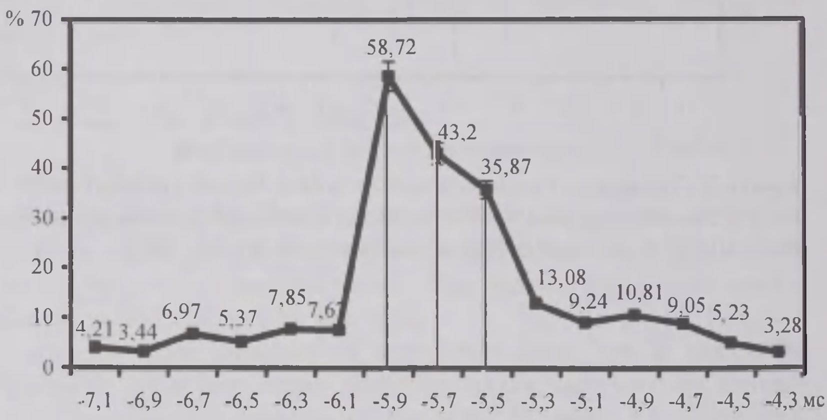

Figure 5. Dynamics (in %) of heteronymous m. soleus H-reflex reinforcement in 17–18 year-old teenagers and 22–27 year-old men under heteronymous conditioning stimulation of n. femoralis, with different delays between stimuli (mean ± SE).

The experimental research results have shown that 14–15 year-old teenagers demonstrate the maximum intensity of PI of the m. rectus femoris Ia afferent fibers as compared to 9–12 year-old boys, 17–18 year-old teenagers, and 22–27 year-old men. A tendency for PI increase is observed in 14–15 year-old teenagers when a delay of –4.9 ms is used, and in 9–12 year-old boys when a delay of –5.3 ms is used (Figure 6). Thus, in teenage boys, the heteronymous m. soleus H-reflex reinforcement decreases by 16.15% with a delay of –4.9 ms, as compared to a –5.3 ms interval; by 8.84% as compared to a –5.1 ms interval; and by 14.72% as compared to a delay of –4.7 ms. In 9–12 year-old boys, the heteronymous reinforcement of the monosynaptic m. soleus reflex decreases by 13.84% with a delay of –5.3 ms, as compared to a delay of –5.1 ms; by 9.72% as compared to a delay of –4.9 ms; and by 11.94% as compared to an interval of –4.7 ms.

Figure 6. Heteronymous m. soleus H-reflex reinforcement (in %) in persons of different age groups under heteronymous conditioning stimulation of n. femoralis, with different delays between stimuli (mean).

Analysis of Figure 6 shows that, in the group of 22–27 year-old men, more intense PI of the m. rectus femoris Ia afferent fibers under heteronymous conditioning stimulation of n. femoralis was observed when delays of –5.9; –5.7; –5.5 ms were used, as compared to 17–18 year-old teenagers. An evidence of this is less average group values of heteronymous reinforcement of monosynaptic m. soleus reflex in these persons being tested. This tendency was observed with all intervals between the conditioning stimulus and the testing stimulus, and particularly with a delay of –5.5 ms. A similar tendency was observed with delays of –5.9 and –5.7 ms between the conditioning stimulus and the testing stimulus. Thus, in 22–27 year-old men, this value decreases by 20.84% and 9.29% with a delay of –5.5 ms, as compared to –5.9 ms and –5.7 ms intervals. In 17–18 year-old teenagers, the maximum m. soleus H-reflex reinforcement and, therefore, the least intensity of PI of the m. rectus femoris Ia afferent fibers were observed with delays of –5.9 ms and –5.7 ms, as compared to a –5.5 ms delay. Thus, in 17–18 year-old teenagers, the heteronymous m. soleus H-reflex reinforcement increases by 15.52% and 22.85% with delays of –5.9 ms and 5.7 ms, as compared to a delay of –5.5 ms.

The research results have shown that, under homonymous vibration stimulation of tendo calcaneus, the presynaptic inhibition of m. soleus afferent fibers is considerably higher in 9–12 year-old boys than in 14–15 year-old teenagers (Figure 7).

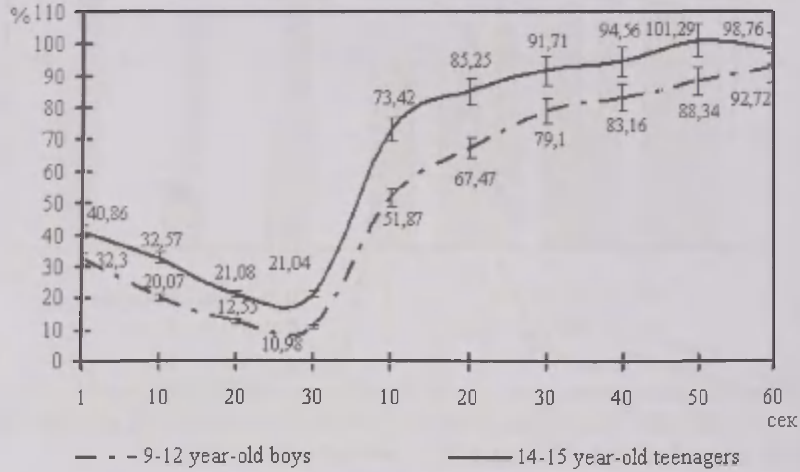

Figure 7. Dynamics (in %) of m. soleus H-reflex amplitude during vibration stimulation of tendo calcaneus (A) and aftereffect period (B) in 9–12 year-old boys and 14–15 year-old teenagers (mean ± SE).

Analysis of Figure 7 shows that the same tendency of m. soleus H-reflex amplitude suppression dynamics under vibration stimulation of tendo calcaneus is observed in both age groups. The maximum PI values are observed at the 30th second of vibration stimulation of tendo calcaneus, while the minimum values, as compared to rest, are observed at the 1st second of vibration. Thus, at the 30th second of vibration stimulation, the m. soleus H-reflex decrease, as compared to rest, was 1.10 mV (89.02%) in 9–12 year-old children, and 2.67 mV (78.96%) in 14–16 year-old teenagers.

The research results demonstrate different rates of recovery of PI of m. soleus primary afferent fibers after vibration stimulation of t. calcaneus in 9–12 year-old boys and 14–15 year-old teenagers. Thus, teenagers showed faster presynaptic inhibition recovery after the vibration stimulation as compared to 9–12 year-old boys. An evidence of this is faster increase of m. soleus H-reflex amplitude to the background values after vibration stimulation in 14–15 year-old boys than in 9–12 year-old boys. In 14–15 year-old boys, the recovery of PI of the m. soleus la afferent fibers was observed at the 30th second after the vibration end, while with 9–12 year-old boys, this was observed at the 40th second (Figure 7).

DISCUSSION

Different human ontogenesis periods are described with different intensities of the presynaptic inhibition of m. rectus femoris Ia afferent fibers. Results of our researches demonstrate that the intensity of PI of the Ia fibers, in the relative muscular rest condition, is higher in 14–15 year-old teenagers than in 9–12 year-old boys. This can probably be explained by the fact that the afferent link development is still being finished during the teenage period, which is interrelated with the stabilization of many basic motion parameters and movement qualities during adolescence. It should also be noted that intracortical structural transformations of the brain are still taking place in 9–12 year-old children. Different modulations of PI of the spinal motoneurons in 9–12 year-old children and 14–15 year-old teenagers may be due to supraspinal influences and probably depend on the degree of maturation of upper parts of the nervous system.

Under heteronymous conditioning stimulation of n. femoralis in 17–18 year-old teenagers, the presynaptic inhibition of the m. rectus femoris la afferent fibers is less intense than in the other groups under study, which was expressed in higher m. soleus H-reflex reinforcement in these persons being tested. These changes may be caused by heterochronous development of supraspinal structures in the human central nervous system. In the group of 22–27 year-old men, decrease of the heteronymous reinforcement of monosynaptic m. soleus H-reflex was observed, which shows that PI of the m. rectus femoris Ia afferent fibers is more intense in this group. Our results agree with data obtained in the research by Morita et al. [7]. These data show that the heteronymous m. soleus H-reflex reinforcement decreases with age and, as a result, the intensity of PI of the m. rectus femoris Ia afferent fibers increases. Similar results were obtained when the heteronymous reinforcement of m. rectus femoris in the muscular rest condition and in the standing position in normal conditions in young and elderly people was compared [4].

Under homonymous vibration stimulation of tendo calcaneus, the presynaptic inhibition of m. soleus afferent fibers is considerably higher in 9–12 year-old boys than in 14–15 year-old teenagers. In the after-vibration period, the presynaptic inhibition of the spinal α-motoneurons of m. soleus reaches the initial level faster in 14–15 year-old teenagers than in 9–12 year-old boys. It is likely that the limitation of the afferent pulse flow to nerve centers under homonymous vibration stimulation of tendo calcaneus in 9–12 year-old boys is determined by the presynaptic inhibition mechanism, which is associated with the course of neuromuscular apparatus development in this age.

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AGE-RELATED CONTRACTILE CHANGES IN PLANTARFLEXOR MUSCLES IN WOMEN: ASSOCIATON WITH RECREATIONAL PHYSICAL ACTIVITY

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ABSTRACT

Isometric maximal voluntary contraction (MVC) force and electrically evoked twitch characteristics of the plantarflexor muscles were compared among the groups of recreationally physically active (RPA) and nonactive (RPN) women of 3rd (n = 29 and n = 22, respectively), 4th (n = 31 and n = 17, respectively), 5th (n = 27 and n = 14, respectively) and 6th (n = 16 and n = 12, respectively) decade. RPA women exercised regularly in groups of recreational gymnastics 2–3 times per week. MVC force was significantly reduced from 6th decade in RPN women, whereas did not differ significantly in measured groups of RPA women. A significant decrease in MVC force relative to body mass was found from 5th decade and it was more pronounced in RPN women. Twitch peak force was reduced from 6th decade in RPA and RPN women. A reduction in twitch postactivation potentiation was observed from 5th decade in RPA and from 6th decade in RPN women. Twitch contraction time was prolongated from 4th decade in RPA and RPN women, whereas twitch half-relaxation time did not differ significantly in measured groups. We concluded that recreational physical activity had a positive effect on voluntary force-generation capacity of plantarflexor muscles in women, whereas it did not have marked effect on measured twitch contraction characteristics.

Key words**:** ageing, human skeletal muscles, isometric twitch, recreational gymnastics

INTRODUCTION

Ageing is associated with significant structural and functional changes in the human neuromuscular system. A reduction in maximal voluntary and electrically evoked force-generation capacity of the human skeletal muscles, and a prolongation of time-course of the evoked contraction are well-known features of ageing [12, 13, 14, 17]. Age-related contractile changes in skeletal muscles has been attributed to the changes in muscle fibre composition and decrease in muscle mass [3, 6]. The changes in neuromuscular function with ageing can be associated with alterations in hormonal balance and the decline in habitual physical activity [10]. It is well established that sedentary lifestyle is associated with acceleration of age-related changes in neuromuscular function. The decrease in muscle mass in middle and older ages (sarcopenia) is often combined with sedentary lifestyle [16]. Most previous ageing studies assessing the effect of physical training on isometric maximal voluntary contraction (MVC) force and/or electrically evoked contractile characteristics of skeletal muscles have usually measured strength (resistance) training in middle-aged and/or older women or men [5, 18]. However, the effect of long-term recreational gymnastics often practised by women (aerobics, flexibility and stretching exercises) on age-related changes in contractile characteristics of the skeletal muscles in middle and older ages is not well understood. Therefore, it should be within scientific and practical interests to examine to which extent the regular gymnastic-type recreational physical activity may influence the MVC force and electrically evoked twitch contractile characteristics of the skeletal muscles in women and whether it may vary to some extent between different age groups.

The aim of this study was to compare isometric MVC force and electrically evoked twitch characteristics of the plantarflexor muscles among the groups of recreationally physically active (RPA) and nonactive (RPN) women of 3^{rd}, 4^{th}, 5^{th} and 6^{th} decade. Therefore, we investigated the effect of ageing in the contractile changes in skeletal muscles in women, and we tested also the hypothesis that long-term gymnastics-type recreational physical activity can reduce the possible age-related contractile changes.

METHODS

Subjects

A total of 168 women agreed to participate in the present study. The subjects were distributed into 8 groups: (1) 3rd decade RPA (aged 20–29 years, n = 29), (2) 3rd decade RPN (aged 20–29 years, n = 22), (3) 4th decade RPA (aged 30–39 years, n = 31), (4) 4th decade RPN (aged 30–39 years, n = 17), (5) 5th decade RPA (aged 40–49 years, n = 27), (6) 5th decade RPN (aged 40–49 years, n = 14), (7) 6th decade RPA (aged 50–59 years, n = 16), (8) 6th decade RPN (aged 50–59 years, n = 12). The subjects were screened by a questionnaire to exclude those with diagnosed musculoskeletal and cardiovascular disorders. All subjects completed a questionnaire to assess their leisure-time physical activity. The subjects who performed > 3 h of recreational physical activity per week for longer than 12 months were classified as RPA. All RPA women exercised regulary in groups of recreational gymnastics (aerobics, flexibility and stretching exercises) 2–3 times per week. None of them had any backround in competitive sports of any kind. RPN women were not engaged in recreational physical activity in leisure-time. Home- and work-related physical activity was not considered in this study. We therefore limited physical activity to activities that were intended for recreational and training purposes. The physical characteristics and isometric MVC force of the plantarflexor muscles of the subjects are presented in Table 1. All the subjects were informed of the procedures to be utilized as well as the purpose of the study and their written informed consent for participation was obtained. The study carried the approval of the University Ethics Committee for Human Studies.

Table 1. Age and anthropometric characteristics of the subjects (mean ± SE)

Groups	n	Age (yrs)	Height (cm)	Body mass (kg)	BMI ($kg \cdot m^{-2}$)
3rd decade RPA	29	24.1±0.6	166.9±1.2	63.3±1.6	22.7±0.4
3rd decade RPN	22	23.8±0.6	167.8±1.5	66.9±2.5	23.9±0.5
4th decade RPA	31	34.7±0.5	167.8±1.0	66.4±1.7	23.5±0.5
4th decade RPN	17	34.6±0.9	165.5±1.4	63.8±1.5	23.3±0.6
5th decade RPA	27	44.5±0.6	163.7±0.9	65.2±2.2	24.2±0.6
5th decade RPN	14	45.3±0.8	164.5±2.0	71.6±3.0	26.5±1.0
6th decade RPA	16	53.4±0.8	163.8±1.7	71.9±2.7	26.9±0.9
6th decade RPN	12	54.9±0.9	161.8±1.4	73.7±2.6	27.5±1.0

BMI – body mass index
RPA – recreationally physically active
RPN – recreationally physically nonactive

Experimental protocol

During the measurment, the subjects were seated in a specially designed chair with the dominant leg flexed to 90° at the knee and ankle, and mounted inside a metal frame [13]. The foot was connected to an aluminium footplate by inelastic Velcro straps at the location. A strain-gauge transducer connected on the footplate by a rigid bar sensed forces acting on the footplate. Signals from the strain-gauge transducers were linear from 10 to 1600 N. The force signals were sampled at the frequency of 1 kHz and stored on a computer hard disk.

Twenty-four to 48 hours before collecting data the subjects were given instructions and the testing of isometric MVC force of the plantarflexor muscles and electrical stimulation procedures were demonstrated. This was followed by a practice session to familiarize the subjects with the procedures. The determination of the subject's dominant leg was based on a kicking preference.

To measure isometric MVC force of the plantarflexor muscles, the subjects were instructed to push the footplate as forcefully as possible for 2–3 s. Strong verbal encouragement and visual feedback were used during contractions to motivate the subjects. The greatest force of the three maximal efforts was taken as the isometric MVC force. A rest of

2 min was allowed between each of three attempts. The ratio of MVC to body mass was calculated.

The determine the contractile properties of the plantarflexor muscles during an isometric twitch, the posterior tibial nerve was stimulated through a pair of 2 mm-thick, self-adhesive electrodes (Medicompex SA, Ecublens, Switzerland). The cathode (5×5 cm) was placed over the tibial nerve in popliteal fossa and the anode (5×10 cm) was placed under the posterior-medial side of the thigh. Supramaximal rectangular pulses of 1-ms duration were delivered from an isolated voltage stimulator Medicor MG-440 (Budapest, Hungary). During isometric twitch recording the stimulus intensity varied from approximately 25 V to supramaximal (130–150 V) in increments of 30–50%. Single stimuli were given at 30-s intervals and the voltage was increased in increments of 20–25 V until supramaximal twitches were reached. The following characteristics of the isometric twitch were calculated: twitch peak force (PF) – the highest value of isometric force production, contraction time (CT) – the time to twitch peak force, half-relaxation time (HRT) – the time of half of the decline in twitch peak force. The percentage increase in potentiated twitch PF in relation to that at rest was taken as an indicator of postactivation potentiation (PAP).

Statistical analysis

Results are expressed as means and standard errors (± SE). An one-factor ANOVA with the Tukey post-hoc test was used to compare anthropometric parameters, isometric MVC force, and twitch contractile characteristics between groups. A level of $p < 0.05$ indicated statistical significance.

RESULTS

The isometric MVC force of the plantarflexor muscles did not differ significantly in RPA women of different age groups (Figure 1). Two younger (3^{rd} and 4^{th} decade) groups of RPN women had greater ($p < 0.05$) MVC force than the oldest (6^{th} decade) group of RPN women, while no significant differences between three younger (3^{rd}, 4^{th} and 5^{th} decade) and two older (5^{th} and 6^{th} decade) groups were observed. The RPA women of 3^{rd}, 5^{th} and 6^{th} decade had greater ($p < 0.05$) MVC force compared to RPN women of similar age, whereas this parameter did not differ significantly in RPA and RPN women of 4th decade.

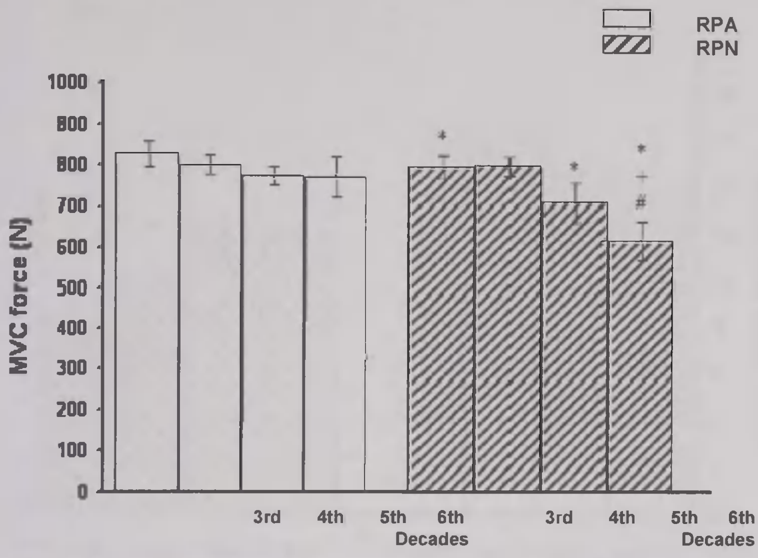

Figure 1. Isometric maximal voluntary contraction (MVC) force in recreationally physically active (RPA) and nonactive (RPN) women (mean ± SE).
*$p < 0.05$ compared with RPA; +$p < 0.05$ compared with 3rd decade; #$p < 0.05$ compared with 4th decade.

The youngest (3rd decade) group of RPA women had greater ($p < 0.05$) isometric MVC force relative to body mass than two older (5th and 6th decade) groups (Figure 2). The isometric MVC force relative to body mass in 4th decade RPA women was greater ($p < 0.05$) compared to 6th decade RPA women, while no significant differences between two younger (3rd and 4th decade) and two older (5th and 6th decade) RPA women groups were found. Two younger (3rd and 4th decade) groups had greater ($p < 0.05$) isometric MVC force relative to body mass than each of the two older (5th and 6th decade) RPN women groups, while no significant differences between two younger groups were observed. The 5th decade RPN women had greater ($p < 0.05$) isometric MVC force relative to body mass than 6th decade RPN women. The RPA women of 3rd, 5th and 6th decade had greater ($p < 0.05$) MVC force relative to body mass compared to RPN women of similar age, whereas this parameter did not differ significantly in RPA and RPN women of 4th decade.

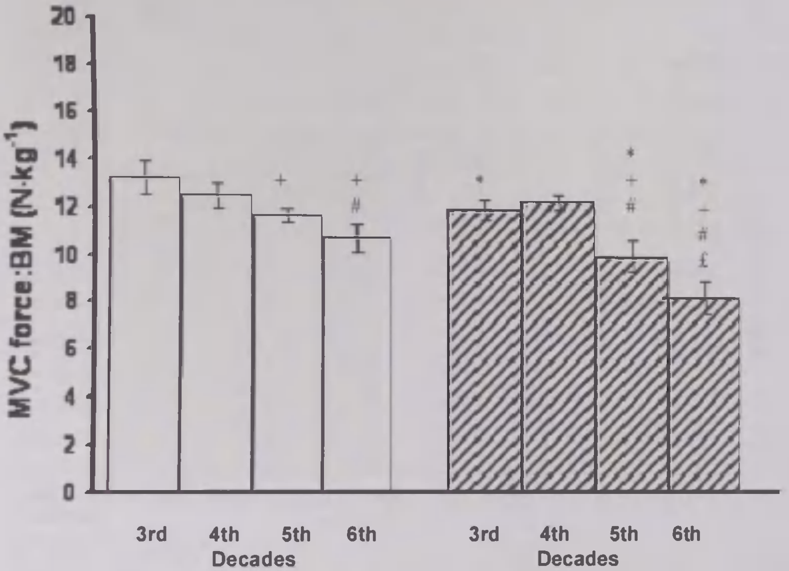

Figure 2. Isometric maximal voluntary contraction (MVC) force relative to body mass (BM) in recreationally physically active (RPA) and nonactive (RPN) women (mean ± SE).
*$p < 0.05$ compared with RPA; +$p < 0.05$ compared with 3rd decade; #$p < 0.05$ compared with 4th decade; £$p < 0.05$ compared with 5th decade.

Three younger (3rd, 4th and 5th decade) groups of RPA women had greater ($p < 0.05$) twitch PF compared to the oldest (6th decade) group, while no significant differences between these three younger groups were found (Figure 3). Twitch PF in two younger (3rd and 4th decade) groups of RPN women was greater ($p < 0.05$) compared to two older (5th and 6th decade) groups, while no significant differences between these two younger and two older groups were observed. This parameter did not differ significantly in RPA and RPN women of similar age.

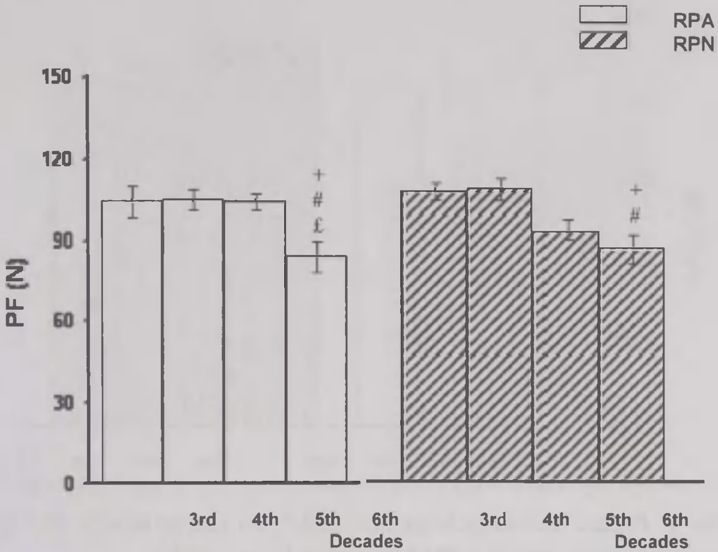

Figure 3. Electrically evoked isometric twitch peak force (PF) in recreationally physically active (PNA) and nonactive (RPN) women (mean ± SE).
+$p < 0.05$ compared with 3rd *decade;* #$p < 0.05$ compared with 4th decade; £$p < 0.05$ compared with 5th decade.

Twitch PAP in youngest (3rd decade) group of RPA women was greater ($p < 0.05$) compared to two older (5th and 6th decade) groups, whereas differences in this parameter between two younger (3rd and 4th decade) and between three older (4th, 5th and 6th decade) groups were not significant (Figure 4). The two younger (3rd and 4th decade) groups of RPN women had greater ($p < 0.05$) twitch PAP than each of two older (5th and 6th decade) groups, while no significant differences between these two younger and two older groups were observed. This parameter did not differ significantly in RPA and RPN women of similar age.

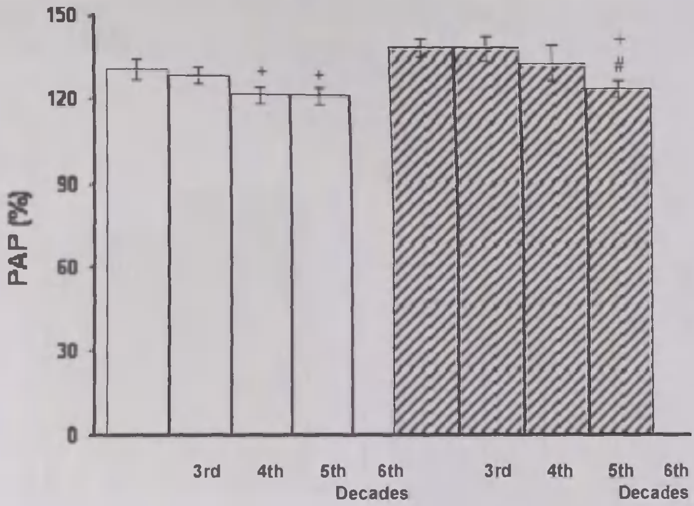

Figure 4. Postactivation potentiation (PAP) in recreationally physically active (RPA) and nonactive (RPN) women (mean ± SE).
+$p < 0.05$ compared with 3rd decade; #$p < 0.05$ compared with 4th decade; £$p < 0.05$ compared with 5th decade.

The 3rd decade RPA women demonstrated shorter ($p < 0.05$) twitch CT than other measured groups of RPA women, while 4th decade group demonstrated shorter ($p < 0.05$) CT than two older (5th and 6th decade) groups (Figure 5). There were no significant differences in twitch CT between two older groups of RPA women. Twitch CT in the youngest (3rd decade) group of RPN women was shorter ($p < 0.05$) compared with other three measured groups of RPN women. No significant differences in twitch CT were observed between three older (4th, 5th and 6th decade) groups of RPN women. Twitch CT did not differ significantly in RPA and RPN women of similar age.

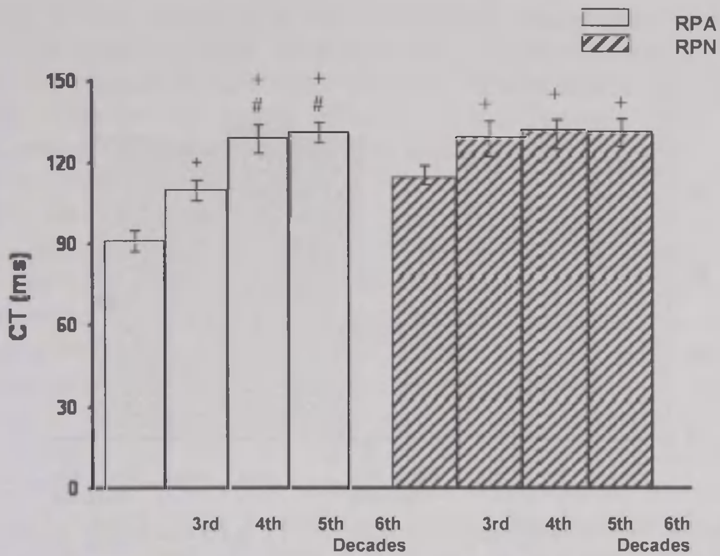

Figure 5. Twitch contraction time (CT) in recreationally physically active (RPA) and nonactive (RPN) women (mean ± SE).
*$p < 0.05$ compared with RPA; +$p < 0.05$ compared with 3rd decade; #$p < 0.05$ compared with 4th decade.

No significant differences ($p > 0{,}05$) emerged in mean values of twitch HRT in RPA and RPN women either between groups or separately in each decade (Figure 6).

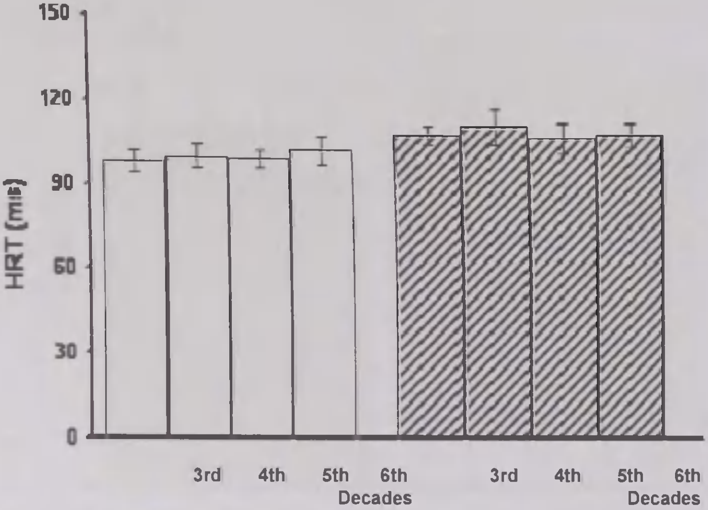

Figure 6. Twitch half-relaxation time (HRT) in recreationally physically active (RPA) and nonactive (RPN) women (mean ± SE).

DISCUSSION

This study indicated that a marked age-related reduction in maximal voluntary force-generating capacity of the plantarflexor muscles in RPN women begins after the age of 50 years. The decrease in MVC force in RPN women with increasing age can be attributed in part to impairment of neural control and in part to changes in muscle fibre composition and muscle mass which is related, possibly, to decrease in quantity and intensity of physical activity [3, 6, 10]. However, isometric MVC force of the plantarflexor muscles did not differ significantly between the groups of 3rd, 4th, 5th and 6th decade RPA women. Isometric MVC force of the plantarflexor muscles in 3rd, 5th and 6th decade RPA women was significantly greater compared to RPN women of similar age.

The present study indicated that in 3rd, 4th decade RPA and RPN women the isometric MVC force relative to body mass was significantly greater than in 5th and 6th decade RPA and RPN women, respectively, while in 5th decade RPN women was it significantly greater than in 6th decade RPN women. Isometric MVC force relative to body mass in RPA women of 3rd, 5th and 6th decade was significantly greater compared to RPN women of similar age. The age-related decrease in muscle force-generating capacity could have been caused by reduced muscle mass in elderly women, associated with a decreased number and atrophy of individual muscle fibres [2, 16], and in sedentary women caused by decline in the quantity and intensity of habitual physical activity [10].

Our previous study indicated that remarkable age-related loss of twitch peak force takes place after 5^{th} decade [13]. The present data indicated that twitch PF was significantly greater in 4^{th} decade group compared to 5^{th} and 6^{th} decade groups, however, there were no significant differences between 3^{rd} and 5^{th} decade groups. The 3^{rd} decade women had significantly greater twitch PF compared to 6^{th} decade women as in RPA as in RPN groups. The age-related decrease in twitch peak force could be caused by loss of muscle mass and a decrease in number of type II muscle fibres with ageing [1].

In the present study, a significant prolongation of twitch CT was found after the age of 30 years in RPA and RPN women. The time course of isometric twitches has been found to depend on the kinetics of the excitation-contraction coupling mechanisms, including intracellular Ca^{2+} movements [8]. The prolonged twitch CT in the elderly suggests decreased efficiency in the function of the sarcoplasmic reticulum to release Ca^{2+} [7]. The results of our study indicated no significant age-related differences in twitch HRT of the plantarflexor muscles, which contradicts several earlier reports [9, 17]. However, this study supported our previous report [13].

Twitch contractile characteristics can be influenced by age-related changes in the series elastic component (SEC) of muscles, which consists of passive (tendon) and active (cross-bridges) elements [4]. It has been shown that ageing is associated with changed stiffness of connective tissue [15]. A more compliant SEC in the muscles tends to decrease twitch force because the relatively brief active state associated with a twitch is not long enough for their more compliant SEC to be fully stretched in order to effectively transit force through the tendon to the bone [11].

It was concluded that gymnastic-type recreational physical activity had a significant positive effect to isometric MVC force and MVC force relative to body mass. However, no marked effect of this type of recreational physical activity on most of measured isometric twitch contraction characteristics of the plantarflexor muscles were observed in this study in women from 3^{rd} to 6^{th} decades.

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THE INTERMITTENT FIELD TEST 45/15: VALIDITY AND PHYSIOLOGICAL DETERMINANTS

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ABSTRACT

This study aimed to validate a new intermittent field test 10×45s/15s (IFT45/15) for assessing peak oxygen uptake (IFT-$\dot{V}O_{2peak}$) and to investigate the relationship between the performance achieved in this test and that obtained during the 30-second Wingate test (WT) in young trained subjects. Moreover, the reproducibility of the mean maximal IFT45/15 speed (IFT-MS) measurement was investigated in a group of children. The first group (23.4± 0.7yr, n = 7) performed the IFT45/15 and WT. During the IFT45/15 gas exchange was measured with a portable breath-by – breath ergospirometer (Oxycon Mobile), heart rate was continuously monitored and IFT-MS was determined. Anaerobic capacity (AC), mean power (MP) and peak power (PP) output were determined during the WT. The second group (15.4 ± 0.7yr, n = 15) performed the IFT45/15 twice and IFT-MS was measured. In the first group, since respiratory exchange ratio and maximal heart rate were 1.21 ± 0.03 and 197 ± 8beats.min^{-1}, respectively, over 15s during the running period, we considered that IFT-$\dot{V}O_{2peak}$ was reached during the exercise period. IFT-MS and IFT-$\dot{V}O_{2peak}$ were significantly correlated and the linear regression equation was determined as follow: IFT-$\dot{V}O_{2peak}$ = 2.907×IFT-MS+8.061 (r = 0.78, P = 0.039, n = 7). IFT-MS was correlated with AC, MP and PP. In children, IFT-MS in the first IFT45/15 was similar and well correlated to that obtained in the second test. These results show that the IFT45/15 is a valid test to estimate IFT-$\dot{V}O_{2peak}$ and suggest that anaerobic energy contribution is important during its realisation. Moreover, this test appears to be reliable in middle school.

Key words: mean maximal speed, peak oxygen uptake, Wingate test, field test, school

INTRODUCTION

Numerous field tests have been developed to determine maximal speed and to predict maximal oxygen consumption [1–3]. Recently, a new intermittent field test 10×45s/15s (IFT45/15) has been developed in the Sport Faculty of Grenoble University (France) to determine mean maximal IFT45/15 speed (IFT-MS) with the minimum of equipment and training of test administrators. This test consists of 10 high intensity runs of 45 s duration interspaced by 15 s recovery periods. The goal of this test is to run the greatest cumulative distance. Nevertheless, at the present time, no information was available on the validity of this test to predict peak oxygen uptake (IFT-$\dot{V}O_{2peak}$). Therefore, the first purpose of this pilot study was to validate the new intermittent field test IFT45/15 for assessing IFT-$\dot{V}O_{2peak}$ in young trained subjects. Moreover, in regard of the characteristics of the IFT45/15 alternating high intensity runs and recovery periods, and the total cumulative duration of the running period (7.5 min), the second objective of this study was to investigate the relationship between the performance realised at the IFT45/15, defined by the IFT-MS measurement, and indices of anaerobic performance provided by the 30-second Wingate anaerobic test (anaerobic capacity, mean and peak power output). Lastly, as we have had an opportunity to test the IFT45/15 in middle school, this study also investigated the reproducibility of the IFT-MS measurement in children during their physical education lessons.

MATERIAL AND METHODS

Subjects

A first group of seven young physical education students (6 males and 1 female) gave their written informed consent to participate to this study. Their mean age (± S.E.M.), mass, height and body mass index were 23.4 ± 0.7 yr, 68.3 ± 2.1 kg, 170 ± 2 cm and 22.5 ± 0.35 $kg.m^{-2}$, respectively. The subjects were volleyball player (n = 1), alpine skiers (n = 2), football players (n = 2), gymnast (n = 1) and ice hockey player (n = 1). A second group of fifteen children (10 males and 5 females) in middle school (age: 15.4 ± 0.7 yr) participated to the reliability study during their physical education lessons.

Experimental design

After a laboratory test on ergocycle ensuring that no subject presented any contraindication to participate to this study, the first group performed the IFT45/15 and 30-second Wingate anaerobic test. Field and laboratory tests were separated by 7–14 days. Subjects were tested 2–3 h after their last meal and refrained from strenuous exercise before each test. The second group underwent only the field IFT45/15 on 2 occasions 7 days apart.

Laboratory tests

The ergocycle test (ErgT) consisted of a continuous incremental maximal oxygen uptake test on a cycle ergometer (Monark 800, Monark, Sweden). After a 5 min warm up (30 watts for female and 60 watts for male subjects), the workload was increased by 15 watts (for females) and 20 watts (for males) every minute until exhaustion. During the test, heart rate (Cardioline ECT WS 2000, Vignate, Italy), ventilation, oxygen consumption and carbon dioxide production were monitored continuously (Brainware, Toulon, France). Both the analysers and pneumotachograph were calibrated before each test using gases of known concentration and a 3-L syringe. Maximal oxygen consumption ($\dot{V}O_{2max}$) was considered to have been reached if at least three of the four following criteria were met: [5] no further increase in oxygen consumption with increasing workload; [8] respiratory exchange ratio >1.1; [9] heart rate ≥90% of the maximal predicted value; and [4] an inability to maintain the required pedalling frequency despite maximum effort and verbal encouragement.

The 30-second Wingate anaerobic test (WT) [4] was performed on a friction belt cycle ergometer (GP 440, Ergomeca, Toulon, France). The test was preceded by a standardised 3 min warm-up without resistance, followed by a 30 s sprint against the calculated external load (Kp = body mass (kg) × 0.075). After a 3 min recovery, subjects maintained a pedal frequency of 60 rpm before the full braking force was applied. Subjects were required to remain seated throughout the test and were verbally encouraged to pedal maximally. After the test, subjects performed a standardised 3 min cool down without resistance. The following parameters were recorded: heart rate, anaerobic capacity (AC), mean power (MP) and peak power (PP) output. AC was defined as the product of the area under the curve (relationship between power output and time) times the calculated imposed external load (Kp). MP was defined as the arithmetic average of the total work performed during the 30 s period. AC, MP and PP were expressed relative to body mass.

Intermittent Field Test 10×45s/15s

Subjects performed the same supervised 10 min warm-up, which included jogging and stretching. Immediately before the test, subjects were given a familiarisation during a trial which simulated the test procedures and conditions and in which procedures were standardized. Each subject was verbally encouraged to perform maximally during the test. Tests were achieved outdoor with stable meteorological conditions (no precipitation, almost no wind, ambient temperature: 14–17°C).

The IFT45/15 is a new fractioned intermittent test with 10 running periods of 45 s interspaced with 15 s of recovery. The goal of this test is to run the maximal cumulative distance during the 10 running periods. The IFT45/15 was performed on a running track with a 400 m loop in which the test's start point was clearly marked on the floor with markers. Several lines were then located and marked every 12.5 m away. The protocol consisted of running around the track at their maximal possibility during each running period. The running distance covered during each 45 s period (RD) was noted and the precision ensured with the help of markers. The IFT-MS was calculated as the sum of the RD divided by the number of total running periods and expressed in $km.h^{-1}$. During IFT45/15, gas exchange was continuously assessed with a portable breath-by-breath ergospirometer (Oxycon Mobile, Jaeger, Germany) calibrated before each test using gases of known concentration and a 2-L syringe. The measurement of gas exchange with the portable Oxycon Mobile has been used in a previous study [5]. IFT-$\dot{V}O_{2peak}$ was determined by taking the higher arithmetic average of the oxygen uptake measured over 15 s during the running period associated with a respiratory exchange ratio greater than 1.1 and an heart rate greater than 90% of maximal heart rate, 2 criteria of maximal exercise. It should be mentioned that in the second group (children group) measurement of gas exchange was not performed. Nevertheless, heart rate was continuously monitored (Polar, S610).

Statistical analysis

Results are presented as mean values ±S.E.M. Data describing IFT-$\dot{V}O_{2peak}$, ErgT-$\dot{V}O_{2max}$, maximal heart rate and IFT-MS were subjected to a paired Student's *t*-test using the Statview software (Abacus Concepts, Cary, USA). Simple regression analyses were performed using the Statview software too and the Pearson's correlation coefficient was used. A P value <0.05 was considered as significant.

RESULTS

IFT45/15 and ErgT

The mean IFT-$\dot{V}O_{2peak}$ was 56.4 ± 2.3 mL.min^{-1}.kg^{-1} (n = 7) and it was associated with a respiratory exchange ratio, ventilation and heart rate of 1.21 ± 0.08, 1.97 ± 0.08 L.min^{-1}.kg^{-1} and 197 ± 8 beats.min^{-1} (100.4 ± 4.1% of the maximum theoretical heart rate value), respectively (n = 7 for each parameter). The mean IFT-MS was 16.6±0.6 km.h^{-1} (n = 7). The IFT-$\dot{V}O_{2peak}$ and IFT-MS values were significantly correlated (r = 0.78, n = 7, P = 0.039). Hence, IFT-$\dot{V}O_{2peak}$ may be estimated from IFT-MS measurement according to the following formula: $\dot{V}O_{2peak}$ (mL.min^{-1}.kg^{-1}) = 2.907 × IFT-MS + 8.061. (n = 7) (Figure 1). Despite that the ErgT was performed to ensure that no subject presented any contraindication to participate to this study, it seems of interest to compare the $\dot{V}O_{2max}$ obtained during this test (ErgT-$\dot{V}O_{2max}$) with IFT-$\dot{V}O_{2peak}$. No significant difference was observed between the means IFT-$\dot{V}O_{2peak}$ and ErgT-$\dot{V}O_{2max}$ (56.4 ± 2.3 and 58.8 ± 4.4 mL.min^{-1}.kg^{-1}, respectively, n = 7, P = 0.452). Moreover, IFT-$\dot{V}O_{2peak}$ and ErgT-$\dot{V}O_{2max}$ values were significantly correlated (r = 0.80, n = 7, P = 0.032).

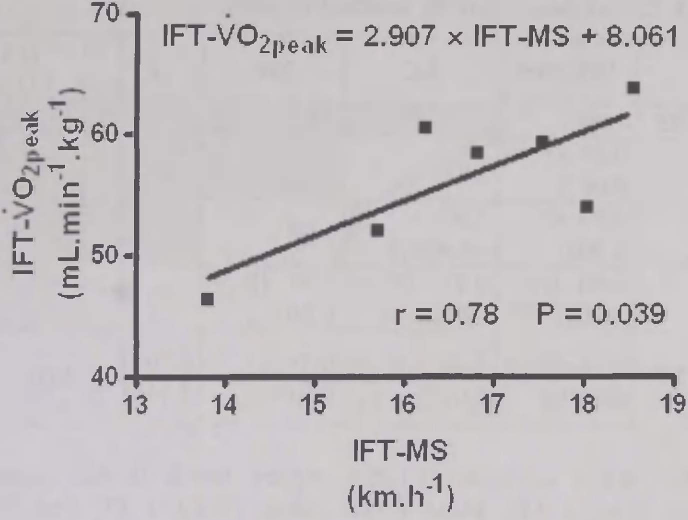

Figure 1. Prediction of the peak oxygen uptake in young trained adults from the measurement of the mean maximal speed value obtained during the field IFT45/15.

IFT45/15: Intermittent Field Test 10×45s/15s; IFT- $\dot{V}O_{2peak}$: peak oxygen uptake; IFT-MS: mean maximal IFT45/15 speed. The number of experiments was 7. The linear regression equation between these 2 parameters was determined and the Pearson's correlation coefficient was used.

Relationships between IFT-MS and anaerobic capacity, mean and peak power output

As shown by the correlation matrix displayed in Table 1, IFT-MS was individually and significantly correlated with AC, MP and PP. Since all these variables were correlated between them, they were not entered in a multiple regression model in order to explain the variance of IFT-MS. Hence, we analysed the influence of each independent variable on IFT-MS separately. Noteworthy, there is a close relationship between PP and IFT-MS ($r = 0.90$, $n = 7$, $P = 0.005$) which attained a greater level of correlation that the relationship between IFT-$\dot{V}O_{2peak}$ and IFT-MS (see above).

Table 1. Correlation matrix for selected variables

	IFT-MS	AC	MP	PP	IFT-$\dot{V}O_{2peak}$
IFT-MS	1.00				
AC	0.89 (P = 0.007)	1.00			
MP	0.89 (P = 0.008)	1.00 (P <0.0001)	1.00		
PP	0.90 (P = 0.005)	0.93 (P = 0.002)	0.93 (P = 0.002)	1.00	
IFT-$\dot{V}O_{2peak}$	0.78 (P = 0.039)	0.84 (P = 0.017)	0.84 (P = 0.019)	0.76 (P = 0.045)	1.00

IFT-MS: mean maximal IFT45/15 speed ($km.h^{-1}$); AC: anaerobic capacity ($J.kg^{-1}$); MP: Mean Power output ($W.kg^{-1}$); PP: Peak Power output ($W.kg^{-1}$); IFT-$\dot{V}O_{2peak}$: peak oxygen uptake ($mL.min^{-1}.kg^{-1}$). Values represented in the Table are the Pearson's correlation coefficients.

IFT45/15 in middle school

In children, the means maximal heart rate and IFT-MS obtained during the second test were similar compared to those measured during the first test (maximal heart rate, 197 ± 11 *versus* 193 ± 13 beats.min^{-1}, P = 0.330; IFT-MS, 12.5 ± 0.6 *versus* 12.5 ± 0.5 $km.h^{-1}$, P = 0.895; n = 15). A significant and good correlation between IFT-MS obtained during the first and second trial was also observed (Figure 2).

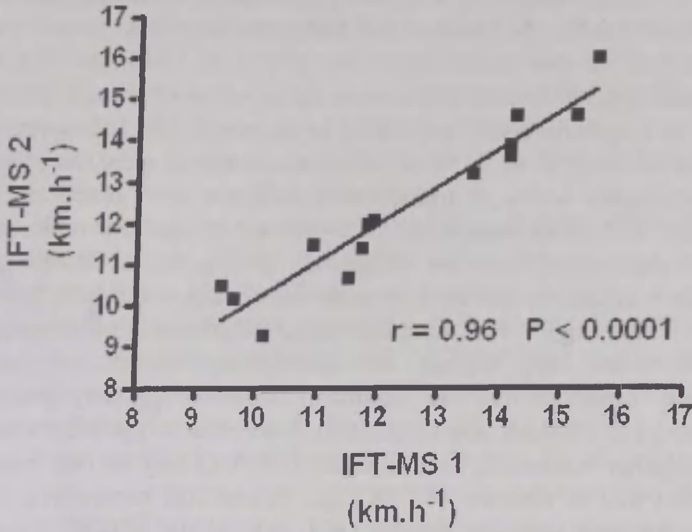

Figure 2. Reproducibility of the mean maximal IFT45/15 speed measurement in children.

IFT45/15: Intermittent Field Test 10×45s/15s; IFT-MS: mean maximal IFT45/15 speed. The number of experiments was 15 for each session. r represented the Pearson's correlation coefficient.

DISCUSSION

The first objective of this study was to validate the IFT45/15 for IFT-$\dot{V}O_{2peak}$ determination. Since respiratory exchange ratio was higher than 1.1 and heart rate was greater that 90% of the maximal predicted value over 15 s during the running period, it can be considered that IFT-$\dot{V}O_{2peak}$ was reached during this time. Moreover, it is in agreement with the fact that the IFT-$\dot{V}O_{2peak}$ was well correlated and, as a matter effect, closely similar to the ErgT-$\dot{V}O_{2max}$. This last point deserves more extensive comments. Indeed, it is generally observed that $\dot{V}O_{2max}$ is higher in running as compared to cycling test [7, 14]. This difference is generally explained by the fact that running solicits higher muscular mass than cycling. Therefore, the reason for the discrepancy between our study and other works is not clear. This might relate to the fact that in our study participants were experts in various disciplines including volleyball, gymnastic, ice hockey, skiing and football. Indeed, in Fernhall and Schneider's studies participants were experts in the same sport [7, 14]. This difference is of importance since it directly impacts on the capacity of muscle groups to reply to a specific exercise (bicycle or running) [12]. Moreover, in the study of Scott et al. [15], in which the subjects were, as in our study, physically active or trained with different sport practices, no significant difference was found between cycle and treadmill test. Another explanation may be suggested. During the IFT45/15 gas exchange was determined by a portable spirometric-telemetric device whereas in the ErgT it was measured using a Brainware metabograph. This difference may explain the discrepancy. Indeed, we have previously observed that the Brainware metabograph may overestimate oxygen consumption (unpublished observation). Nevertheless, taken together our results show that the IFT45/15 may be considered as a valid tool to estimate IFT-$\dot{V}O_{2peak}$. In practical perspective, the linear regression equation between IFT-$\dot{V}O_{2peak}$ and IFT-MS values was determined. Such an equation could be used by coaches to predict IFT-$\dot{V}O_{2peak}$ in young trained subjects from IFT-MS determination. It would be relevant, however, to investigate the influence of different sports (e.g. team sports *versus* individual sports or endurance *versus* sprint) on this equation.

The second objective of this study was to investigate the relationship between the performance realised at the IFT45/15, defined by the IFT-MS measurement, and indices of anaerobic performance provided by the 30-second Wingate anaerobic test. We observed a close correlation between IFT-MS and AC but also with MP and PP values. In particular, correlation coefficient for the relation between IFT-MS and PP is important. These results are not surprising in regard of the characteristics of the IFT45/15 alternating high intensity runs and recovery periods and suggest that the IFT-MS, in the population studied, is linked to the anaerobic performance. This point would be of interest since anaerobic capacity is difficult to measure with non-invasive physiological test. Indeed, even it is accepted that maximal oxygen deficit is an appropriate physiological measure to estimate anaerobic capacity [10, 11] this test methodology has been questioned by some authors [2]. Actually, the Wingate anaerobic test is considered as the most sensitive and reliable assessment of anaerobic capacity [4, 6]. Nevertheless, it is difficult to use in regard of the laboratory based nature of the equipment needed and the standard of training required by the testers. Therefore, utilization of the IFT45/15 may be relevant to predict anaerobic capacity but other investigations are needed. It can be mentioned that other studies have shown that anaerobic performance can be successfully predicted from the performance on the shuttle run test [1, 6]. Nevertheless, the IFT45/15 and shuttle run test are not the same in nature. Therefore, the comparison between these two tests must be cautious.

Lastly, we had the opportunity to test the reliability of the IFT-MS measurement in children in middle school during their physical education lessons. Values of maximal heart rate recorded during the first and second test are in agreement with maximum theoretical heart rate value of children of this age [3]. Therefore, despite that gas exchange was not measured we may consider that IFT-$\dot{V}O_{2peak}$ was reached during these two tests. The mean IFT-MS obtained during the second test was similar compared to that obtained during the first test. Moreover, a significant and high correlation between the IFT-MS values obtained in the first and second test was observed. These results show that the IFT45/15 is a reliable tool to determine IFT-MS in middle school. The reliability of maximal speed measurement is important for teachers because they use this value to evaluate the progression and to individualize the training of children. We believe that the IFT45/15 may offer interesting perspectives in school. Indeed, the IFT45/15 requires minimal equipment and training of assessors. In particular, utilization of a tape recorder is not needed. Moreover, the short duration period and intermittent nature of this test were greatly appreciated by children compared to other field tests (e.g. Vaussenat test, unpublished observation). Repeated short-term high-intensity activities seem also more representative of the spontaneous activity of children [13].

The difference in population (young trained subjects *versus* children), as dictated by circumstantial opportunities, to investigate on one hand the validity of the IFT45/15 and on the other hand its reliability could be perceived as a limitation of our work. Nevertheless, this pilot study provided relevant information on both the validity and reproducibility of the IFT45/15. Moreover, it documents its feasibility in both children and adults.

CONCLUSIONS

This study shows that the IFT45/15 is a valid tool to estimate IFT-$\dot{V}O_{2peak}$ in young trained subjects. Since the IFT45/15 alternates short exercise periods of high intensity with recovery periods, the close relationships between IFT-MS and indices of anaerobic performance is not surprising. However, further studies are needed to assess the influence of anaerobic performance on the result at this test. Moreover, the IFT45/15 appears to be reliable in middle school and may offer interesting perspectives during physical education lessons. Experiments involving various field tests (e.g. shuttle run) could be proposed in a future study to investigate variation of maximal speed measurement.

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TIME-LOSS INJURIES IN KARATE

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ABSTRACT

The purpose of this study was to assess time-loss injuries sustained during karate competition. Subjects were competing at two Open Dutch Karate Championships. Data were collected with simple check-off forms that describe the athlete, nature, site, circumstances, and severity of the injury. The men (11.32/1,000 athlete-exposures; 95%CI: 4.92–17.73) incurred more time-loss injuries than the women (2.44/1,000 athlete-exposures; 95%CI: 2.34–7.22) but this was not statistically significant. The fracture was the dominant injury type in both males (6.60/1,000 athlete-exposures; 95% CI: 1.71–11.49) and females (2.44/1,000 athlete-exposures; 95% CI: 2.34–7.22). The dominant injury mechanism in the men was simultaneous straight punches (5.66/1,000 athlete-exposures; 95% CI: 1.13–10.19) and in the women, impact with surface (2.44/1,000 athlete-exposures; 95% CI: 2.34–7.22). Based on the results of this study, tournament physicians may expect to encounter about 2.5% of karate competitors to incur a time-loss injury.

Key words: Karate, injuries, time-loss

INTRODUCTION

Time-loss injuries in karate have rarely been studied. Time-loss injuries are defined as those that will keep the athlete from completing the present bout and/or subsequent ones and from participating in karate for a minimum of one day thereafter. Several case reports and case series have recounted time-loss injuries in karate [e.g., 4, 7]. The mechanisms of injury included receiving a side kick [4]; faulty technique [e.g., 10]; falls as a result of a leg sweep or throw [20] and receiving unspecified blows [e.g., 7, 12, 22]. Most of the aforementioned time-loss injuries were recorded following practice.

Prospective studies have also reported time-loss injuries incurred by male karate athletes [9, 13, 23]. Mechanisms of injury mentioned in these investigations included non-specified punches and kicks. Arriaza and Leyes [1] reported a rate for severe injuries of 4.40/1,000 athlete-exposures (A-E) collapsed over gender. One A-E refers to one athlete being exposed to the possibility of sustaining an injury while participating in a bout. Severity of injury was based on the World Karate Federation classification. No mechanisms of injury were reported, however, for these severe injuries. The present study was conducted with the purpose of assessing time-loss injuries in karate competition relative to injury type, body part injured, injury mechanism and estimated days lost.

MATERIALS AND METHODS

Injury data were collected at two Open Dutch Karate Championships with simple check-off forms that describe the athlete and nature, site, situation, mechanism, and severity of the injury. These forms are a variation of those used in previous research on martial arts injuries [e.g., 18]. A form was completed for every reported injury at the competition site. An injury was defined as any circumstance for which assistance was sought from the medical personnel. All injuries were diagnosed by the tournament physician, who was a former karate competitor.

Athletes engaged in free-sparring bouts for one round of three (males) or two minutes (females). In case of a draw, a second round was allowed until the first point was scored, which always occurred within the first few seconds of the encounter and well within the time allotted (two or three minutes for females and males, respectively). The competitors wore padding for the fists, the shins, a groin cup for the men and a mouthpiece. The area of competition was matted as a further measure of injury prevention.

Exposure data for calculating injury rates were gathered from records of bouts actually fought. Injury rates were calculated from matches fought using the basic rate formula: (# injuries / # athlete-exposures) x 1,000 = # injuries per 1,000 athlete-exposures (A-E)

Confidence intervals were calculated around the total time-loss injury rates. The risk to incur a time-loss injury was expressed in an odds ratio.

RESULTS

Table 1 depicts the injury rates for time-loss injuries in karate. The males were more at risk of incurring a time-loss injury (OR = 4.40, 95% CI: 0.57–34.11) but this was not significant (p = 0.082). Injuries in the men were sustained to the head and neck (including face): 5.66/1,000 A-E (95% CI = 1.53–9.80) followed by the upper and lower extremities (1.89/1,000 A-E each; 95% CI = 0.73–4.51) and trunk (0.94/1,000 A-E; 95% CI = 0.91–2.79).

Tables 2–5 display the time-loss injuries by body part, type of injury, situation and mechanism, while Table 6 shows the estimated days lost.

Table 1. Time-loss injury rates (95% CI) in adult karate athletes

	Men	Women
# of athletes	489	176
# of athlete-exposures (A-E)	1,060	410
# of injuries	12	1
Total injury rates		
-- per 100 competitors	2.45 (1.06–3.84)	0.57 (0.54–1.68)
-- per 1,000 athlete-exposures (A-E)	11.32 (4.92–17.73)	2.44 (2.34–7.22)

Table 2. Distribution per 1,000 athlete-exposures (95% CI) of time-loss karate injuries by body part

	Men		Women	
Body part	Number	Rate	Number	Rate
Head	1	0.94 (0.91–2.79)		
Jaw	1	0.94 (0.91–2.79)		
Nose	2	1.89 (0.73–4.51)		
Lip	1	0.94 (0.91–2.79)		
Teeth	1	0.94 (0.91–2.79)		
Fingers	1	0.94 (0.91–2.79)		
Wrist	1	0.94 (0.91–2.79)	1	2.44 (2.34–7.22)
Ribs	1	0.94 (0.91–2.79)		
Foot	1	0.94 (0.91–2.79)		
Toes	1	0.94 (0.91–2.79)		
Total	12	11.32 (4.92–17.73)	1	2.44 (2.34–7.22)

Table 3. Distribution per 1,000 athlete-exposures (95% CI) of time-loss karate injuries by type of injury

	Men		Women	
Injury type	Number	Rate	Number	Rate
Concussion	1	0.94 (0.91–2.79)		
Fracture	7	6.60 (1.71–11.49)	1	2.44 (2.34–7.22)
Laceration	2	1.89 (0.73–4.51)		
Ligament - torn	1	0.94 (0.91–2.79)		
Other	1	0.94 (0.91–2.79)		
Total	12	11.32 (4.92–17.73)	1	2.44 (2.34–7.22)

Table 4. Distribution of time-loss karate injuries by situation per 1,000 athlete-exposures (95% CI)

Men			Women	
Situation	No.	Rate	No.	Rate
Attacking – straight punch	7	6.60 (1.71–11.49)		
Unblocked straight punch	2	1.89 (0.73–4.51)		
Other	2	1.89 (0.73–4.51)		
Blocking straight punch	1	0.94 (0.91–2.79)		
Fall			1	2.44 (2.34–7.22)
Total	12	11.32 (4.92–17.73)	1	2.44 (2.34–7.22)

Table 5. Distribution of time-loss karate injuries by mechanism per 1,000 athlete-exposures (95% CI)

Men			Women	
Mechanism	No.	Rate	No.	Rate
Simultaneous straight punches	6	5.66 (1.13–10.19)		
Receiving straight punch	2	1.89 (0.73–4.51)		
Other	2	1.89 (0.73–4.51)		
Impact with surface	1	0.94 (0.91–2.79)	1	2.44 (2.34–7.22)
Simult. straight punch/backfist strike	1	0.94 (0.91–2.79)		
Total	12	11.32 (4.92–17.73)	1	2.44 (2.34–7.22)

Table 6. Distribution per 1,000 athlete-exposures (95% CI) of time-loss karate injuries by days lost

Men			Women	
Days	No.	Rate	No.	Rate
< 7 days	2	1.89 (0.73–4.51)		
7–21 days	1	0.94 (0.91–2.79)		
> 21 days	9	8.49 (2.92–14.04)	1	2.44 (2.34–7.22)
Total	12	11.32 (4.92–17.73)	1	2.44 (2.34–7.22)

DISCUSSION

Table 7 shows comparative rates for time-loss injuries in karate and taekwondo. It is hypothesized that adult females may be more inclined to report an injury [2, 5], but that those reported by the males are of a more serious nature. A recent study revealed female karateka younger than 18 years to incur most general injuries (22.50/100 exposure minutes, 95%CI = 13.33–35.56) in 1997. In 2002, women ≥ 18 years sustained most general injuries (15.53/100 exposure minutes, 95% CI = 10.63–21.93) [11].

In terms of time-loss injuries, the female karateka collapsed over age did not report any in 1997 and 2002. The men, when collapsed over age, had an incidence rate of 0.34/100 exposure minutes (95% CI = 0.11–0.79) in 1997 for injuries that required withdrawal from the competition (grade 2). In 2002, the men incurred an incidence rate for grade 2 injuries of 0.11/100 exposure minutes (95% CI = 0.01–0.39) and 0.05/100 exposure minutes (95% CI = 0.001–0.30) for injuries requiring hospital admission (grade 3 injuries) [11].

Table 7. Comparative time-loss injury rates (95%CI) per 1,000 athlete-exposures in karate and taekwondo

Martial art/Study	Men	Martial art/Study	Women
Karate (this study)	11.32 (4.92–17.73)	Karate (this study)	2.44 (2.34–7.22)
Karate [6]	5.53 (2.52–8.54)	Karate [24]	8.93 (8.57–26.43)
Karate [8]	1.98 (1.91–5.87)	Taekwondo [16]	23.03 (15.71–30.35)
Karate [13]	47.46 (29.88–65.04)	Taekwondo [17]	9.68 (1.27–20.63)
Karate [23]	25.89 (13.20–38.58)	Taekwondo [18]	8.77 (8.42–25.96)
Karate [24]	7.69 (2.36–13.02)	Taekwondo [26]	13.51 (1.78–28.80)

The Table 7 represents a mixture of single tournament studies on karate [13] and taekwondo [17, 18, 26]; studies on injuries sustained at multiple tournaments of karate [6, 8, 23] and of taekwondo [18]; studies on karate injuries incurred at tournaments where padding was not worn [13, 23] and where they were [6, 8] as well as those reporting combined time-loss injury rates sustained by young and adult male and female semi-contact karateka (karate athletes) [6]. The information in the Table 7 seems to suggest that time-loss injury rates in karate are among the lowest compared to taekwondo. It is expected that they will decrease if more tournaments are covered.

In the sample investigated, no body part sustained more time-loss injuries than another with the possible exception of the nose in the males. Johannsen and Noerregaard [9], who covered three tournaments where padding was worn, found a similar time-loss injury rate for the nose (1.85/1,000 A-E, 95% CI = 1.53–5.23) in males as that in the present study. However, the head most often incurred a time-loss injury with a rate of 12.76/1,000 A-E (95% CI = 3.82–21.70). McLatchie [13] also found the head most often sustaining a time-loss injury in male karateka at one tournament, with a rate of 11.86/1,000 A-E (95% CI = 3.07–20.65). The rules called for no contact, while no padding was used at the competition McLatchie [13] covered. In addition, the skill level of the athletes varied from beginners to internationally competing karateka as opposed to that in the present study, which only dealt with internationally competing athletes.

Another early study [23], which covered six non-contact karate tournaments for males where no padding was worn, reported the jaw to be most often affected by a time-loss injury (11.33/1,000 A-E, 95%

CI = 2.94–19.72). In this case the skill level varied from beginners to very experienced athletes. The time-loss injury to the ribs as shown in Table 2 is a cause for concern, since it was found that blows to the trunk may lead to fatal injuries [21].

More research is needed to reveal which body part is at higher risk to sustain a time-loss injury. As well, female karateka should be included in this research, since hardly any comparative data exist in the literature on karate injuries in girls or women. A prospective Finnish study reported one time-loss injury to the nose in an adult female karateka with an injury rate of 8.93/1,000 A-E (95% CI = 8.57–26.43) [24]. Full-contact female taekwondo athletes recorded the ankle to most frequently incur a time-loss injury [16]. The reason for this difference between karate and taekwondo is not clear. The number of tournaments covered for taekwondo (six) may have played a role. In other words, with continued research on karate injuries, the body part most often sustaining a time-loss injury may differ from the one reported here.

The fracture was the most often occurring time-loss injury in the current investigation, which was also found in other prospective studies on karate. For instance, Stricevic et al. [23] reported an injury rate of 8.09/1,000 A-E (95% CI = 1.00–15.18) for fractures as the most often occurring time-loss injury. McLatchie et al. [14] also found the fracture to be the most often occurring time-loss injury with a rate of 2.70/1,000 A-E (95% CI = 1.78–3.62). Just like the present study, McLatchie et al. [14] covered tournaments where padding was worn by the karateka, which is contrary to those investigated by Stricevic et al. [23]. However, McLatchie et al.'s [14] study lasted four years, as opposed to Stricevic et al.'s [23] or the present one. As alluded to above it is hypothesized that the injury rate will decrease with an increasing number of competitions investigated.

On the other hand and contrary to the studies mentioned above, Johannsen and Noerregaard [9] as well as McLatchie [13] found the cerebral concussion to be the most frequently occurring time-loss injury with rates of 12.76/1,000 A-E (95% CI = 3.82–21.70) and 11.86/1,000 A-E (95% CI = 3.07–10.65), respectively. The Danish study [9] included karateka wearing protective equipment as opposed to those in McLatchie's [13]. It is not clear why these differences exist. One possibility is the differential treatment of head blows by the referees, who covered the tournaments where the various studies were done. For instance, Tuominen [24] mentioned that more penalties were recorded after punches to the head as compared to other techniques. It is conceivable that this practice differs per country or even per competition within a country.

No injury situation and mechanism for time-loss injuries were reported in the literature of prospective studies on karate injuries. In full-contact taekwondo, the unblocked roundhouse kick was the situation and receiving one was the mechanism that led to time-loss injuries in the men [17]. In the women, the injury situation was attacking with a roundhouse kick and receiving a spinning back kick as the injury mechanism [17].

Before padding was introduced for the head, arms and shins in full-contact taekwondo, the roundhouse kick was also found to be predominantly implicated in time-loss injuries in male competitive athletes [25]. More research is needed to elucidate the injury situation and mechanism of time-loss injuries in karate to gain better insight in preventive measures to be taken to help minimize them, especially since the days lost as a result of most of these injuries were equal to or in excess of three weeks (see Table 6). In addition, as some of these time-loss injuries are not reported [3], the time-loss injury rate is probably higher than that presented in this study.

Johannsen and Noerregaard [9] as well as McLatchie et al. [14] have shown that padding reduced the number of fractures in competition. On the other hand, the injury rate for cerebral concussions was not appreciably affected by the use of padding alone [9, 15]. However, padding and other preventive measures, such as educating the karateka, coaches and referees regarding injury risk and prevention did lower the injury rate for cerebral concussions [14]. Therefore, and since padding as such will not off-set the acceleration of the head that is thought to be related to the occurrence of cerebral concussions [19], a more comprehensive package of preventive measures is needed as shown by McLatchie et al. [14], which should also include stricter control of the bouts by the referees and judges [15] as well as rule modifications, such as more readily rewarding a score to the body [24].

Physicians covering karate tournaments may expect to encounter about 2.5% of all competitors to incur a time-loss injury. Provisions may have to be made to more adequately deal with such injuries. For instance, speedy transportation to a nearby hospital should be available at all times. The first aid station may be adjusted in terms of equipment and diagnostic tools available to optimize adequate on-site help to the patients sustaining a time-loss injury.

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AUTONOMY SUPPORT FROM PHYSICAL EDUCATION TEACHERS, PEERS AND PARENTS AMONG SCHOOL STUDENTS: TRANS-CONTEXTUAL MOTIVATION MODEL

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ABSTRACT

This study proposes a motivational sequence in which perceived autonomy support from teachers in a physical education context and from peers and parents in a leisure-time physical activity context predicts autonomous motivation, intentions, and physical activity behaviour in leisure time. Also the differences in the components of this model between girls and boys are observed.

Participants, 626 students (Males = 228, Females = 398, M Age = 14.9 years, SD = 1.3, range: 13 to 18), completed measures of perceived autonomy support, autonomous and controlling forms of motivation in both contexts, and attitudes, subjective norms, perceived behavioural control and intentions. The analysis of model indicated that the autonomous support from teacher had statistically significant direct effect only on motivation in physical education context. The autonomous support from parents was related beyond the motivation in both contexts also with attitude, subjective norms and perceived behavioural control. Boys perceived more autonomous support from teacher than girls, whereas no significant difference was followed in respect of autonomous support from peers and parents. Boys reported higher values of intention, attitude and motivation and were more physically active in leisure time than girls.

Key words: self-determination theory, motivation, leisure time physical activity, gender differences

INTRODUCTION

One of the objectives for physical education (PE) is to motivate young people towards regular leisure-time physical activity outside of school. Although there is considerable evidence identifying the motivational factors that are positively associated with physical activity behaviour in young people [3, 30, 35, 36], few studies have examined the process by which motivational factors in PE are translated into physical activity participation in a leisure-time [18, 29]. A great body of research, mostly based in North America [11, 15, 29, 33], reveals positive relations between parents' and teachers' autonomy-support and students' intrinsic and autonomous self-motivation in school, self-esteem, and perceived competence. According to self-determination theory (SDT) [7, 28] autonomy is one of the basic human needs. Autonomy, as defined within SDT, pertains to actions that are self-endorsed and based on one's integrated values or interests. It means that autonomous actions have an internal perceived locus of causality – the phenomenal sense of emanating from the self [26]. By contrast, the actions that are not under person control have an external perceived locus of causality. The theory argues that people are naturally prone to self-organize action and that the sense of choice, congruence, and initiative that characterizes autonomy is a necessary aspect of healthy functioning. Several researchers have investigated the effects of autonomy-support from coaches or teachers and parents in many domains, including sport [9, 10, 14] and PE [18, 31]. Specifically, the findings of these studies confirmed the statement that perceiving others as controlling one's behaviour has a markedly negative affect on self-motivation and vs. perceiving others as supporting one's behaviour has positive affect on self-motivation [28].

Recently, Hagger et al. [18] developed the trans-contextual model to investigate the determinants of the intentional physical activity behaviour among adolescents. The model adopts motivational constructs and frameworks from SDT [6], the theory of planned behaviour (TBP) [1] and the hierarchical model of motivation [34]. This model allows investigating the processes by which motivation for physical activity in a PE context is transferred into a leisure-time physical activity context. An important point of these theories is that they provide complementary explanations of the complex motivational processes involved in intentional behaviour. SDT provides the starting point for the trans-theoretical model and the key dispositional motivational constructs that energise behaviour in both PE and leisure-time contexts. The TBP maps the process by which motivational constructs from SDT are translated into action. Finally, the hierarchical model provides a unifying framework that describes the top-down links between the generalized, context-tied SDT constructs and the specific, situational constructs from the TPB.

Tests of the trans-contextual model have provided support for the relationships among the model constructs [18, 19]. Autonomous motivation in PE was found to affect autonomous motivation in a leisure time context. Further, autonomous motives in leisure time were found to influence intention and behaviour via the mediation of the proximal determinants of intentions, namely attitudes, subjective norms, and perceived behavioural control (PBC). Overall, the significant correlation between perceived autonomy support in PE and leisure-time physical activity behaviour was accounted for by the proposed motivational sequence. However in study of Hagger et al. [18, 19] no control was included for the effects of other sources of autonomy support like from peers and parents. Previous research has shown that perceived autonomy support from significant others has a pervasive effect on autonomous motivation and behavioural engagement in tests of SDT [5, 8]. Therefore a more robust test of the trans-contextual model should control for the effects perceived autonomy support from significant others.

Another issue of interest in the present study is concerned with gender differences in observed components of trans- contextual model because physical activity has been shown to decline at a greater rate for girls in the teenage years than for boys [25, 32, 37]. Recently, Ntoumanis [25] noted that pupils who participated in optional PE were less amotivated and more self determined compared with nonparticipants. However, boys scored significantly higher on intrinsic motivation than did the girls. In this study an interesting interaction emerged between gender and participation status predicting automomy need satisfaction. Male participants and nonparticipants did not differ in autonomy need satisfaction, but female participants had significantly higher scores than female nonparticipants. On the other hand, in respect of the perception of the autonomy support provided by their teachers no gender differences were found between participants and nonparticipants. Further, although Standage, Duda & Ntoumanis [31] found support for the invariance of the motivational processes embraced by SDT across gender, the path between need satisfaction and introjected regulation was significant for the female school students, but non-significant for the male sample.

However, knowing gender differences in the perception of the autonomy support provided by peers and parents and also in the other components of trans-contextual model by which motivational factors in PE are translated into physical activity participation in a leisure-time may be valuable information for PE teachers to promote enjoyable engagement in PE, and to foster future physical activity among girls.

The aims of this study were to test the applicability trans-contextual motivational model on Estonian schoolchildren sample with adding the measures of autonomy support from peers and parents and find whether the differences in the components of this model exist between girls and boys.

METHOD

Research Design

A three-wave prospective design was used. At the first occasion of data collection (time 1), self-report measures of perceived autonomy support in PE and the perceived locus of causality in a PE context were administered [18]. One week later (time 2), a second questionnaire containing measures of the components of the TPB [1] and perceived locus of causality in a leisure-time physical activity context [24] was administered. After five weeks, self-reported physical activity behaviour was measured at a third point in time (time 3).

Participants

Participants were 626 students (Males = 228, Females = 398, M Age = 14.9 years, SD = 1.3, range: 13 to 18) studying in seven different schools in Estonia. In all cases, the school principals, the class-teachers and students granted initial consent for data to be collected in their schools. Students completed the questionnaires in the class-teacher lessons and they were separated so that they could not copy responses. To preserve confidentiality, participants were asked not to report their names. Prospective responses were matched with baseline responses using birth date and gender.

Measures

Three measures of perceived autonomy support were used with respect to three referent groups: PE teachers, peers, and parents [18, 38]. Ryan and Connell's [27] perceived locus of causality scales modified for use in a PE context to measure autonomous motivation were used. Mullen, Markland and Ingledew's [24] Behavioural Regulations in Exercise Questionnaire was used to measure perceived locus of causality in a leisure-time context. Measures of the TPB constructs designed by Hagger et al. [18] according to published guidelines [2] were used. Leisure-time physical activity behaviour was assessed time 3 using an adapted version of Godin and Shepherd's [13] Leisure-Time Exercise Questionnaire (LTEQ).

The previous cross-cultural studies [20, 21] showed the acceptable validity of these instruments among Estonian school students.

Data analysis

Calculation the composite variables for path analysis and model estimation. Participants' level of autonomous motivation in the PE and leisure time physical activity was measured by a relative autonomy index (RAI) that was calculated from the perceived locus of causality constructs using the procedures outlined by Guay, Mageau, and Vallerand [16]. Higher scores on this index reflect higher levels of self-determined motivation. Composite variables for the TPB constructs and the perceived autonomy support constructs were also computed. From the goodness of the fit indexes Comparative Fit Index (CFI) and Root Mean Square Error of Approximation (RMSEA) were used to evaluate the adequacy of model by the statistical program LISREL 8.51. A cut-off value of .90 or above for the CFI is typically considered an acceptable criterion for model fit, although a value greater than .95 is preferable. A critical value of .08 or below for the RMSEA was considered satisfactory for good fit [23]. Differences between males and females students were estimated by the Independent T Samples Test. Equality for variances of observed variables was tested by Levene's test.

RESULTS

Descriptive statistics and intercorrelations for the composite study variables are given in Table 1. Standardized path coefficients of the trans-contextual model are presented in Figure 1. The values of fit indexes CFI = .99 and RMSEA =. 034 (CI .00 – .065) confirmed the model fit.

Table 1. Intercorrelations among the trans-contextual model components

	M	SD	1	2	3	4	5	6	7	8	9
1. Intention	4.79	1.63									
2. Attitude	5.67	1.05	.58								
3. Perceived behavioural control	5.28	1.29	.63	.55							
4. Subjective norms	4.96	1.23	.46	.43	.60						
5. Motivation index in PE context	1.73	2.33	.28	.37	.22	.11					
6. Motivation index in leisure time context	5.49	4.61	.39	.47	.37	.23	.46				
7. Autonomy support from PE teacher	4.40	1.09	.18	.29	.20	.11	.44	.21			
8. Autonomy support from peer	4.64	1.17	.50	.49	.47	.49	.26	.40	.26		
9. Autonomy support from parent	4.96	1.18	.51	.60	.60	.64	.30	.43	.27	.68	
10. Physical activity	4.28	1.29	.60	.43	.44	.34	.26	.31	.24	.34	.63

All correlations are statistically significant, $p < .01$

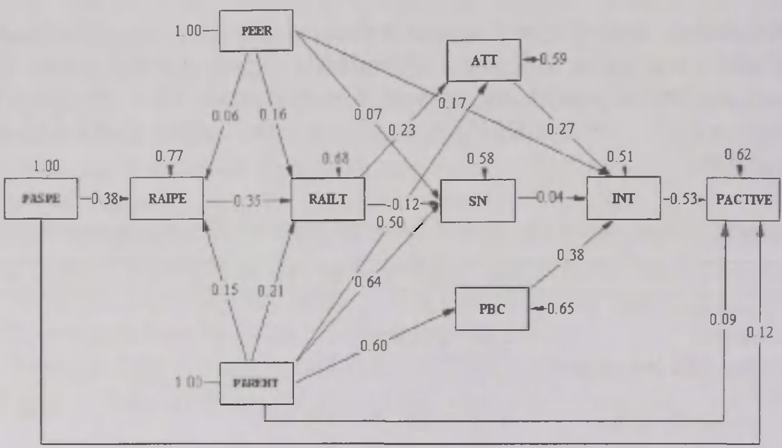

Figure 1. A path model including autonomous support of teacher, peer and parent

Abbreviations: RAIPE – Motivation index in PE context, PAILT – Motivation index in leisure time context, PASPE – Autonomy support from PE teacher, PEER – Autonomy support from peer, PARENT – Autonomy support from parent, INT – intention, ATT – attitude, PBC – perceived behavioural control, SN – subjective norms and PACTIVE – physical activity.

Note: Standardized path coefficients below 0.1 are statistically not significant at $p < 0.05$ level.

Perceived autonomy support from peers and parents exerted significant direct effects on autonomous motivation in the leisure-time context, whereas autonomy support from parents had also effect on autonomous motivation in the PE context. Overall, comparing the effects of perceived autonomy support from the two sources in a leisure time contexts indicates that perceived autonomy support from parents had the most pervasive effects on the attitude, subjective norm, and PBC constructs from the TPB. Perceived autonomy support from teachers and parents exerted also significant direct and indirect effects on physical activity. Perceived autonomy support from peers effected leisure time physical activity only indirectly, mainly via intention. All together, the observed components of the model accounted 38 % of the variance in physical activity behaviour.

Differences in the components of the trans-contextual model are presented in Table 2. Levene's test for equality of variances in observed variables indicated to no significant differences except for perceived autonomy support from teachers. Therefore in comparison of this variable between groups the equality of variances was not assumed. The results showed that boys and girls not perceived autonomy support from peers and parents differently. However, the boys felt the autonomy support from teacher significantly more than girls. No differences were found in the PBC and in subjective norms between boys and girls. Although the motivation for physical activity in leisure time where higher in the girls in comparison with boys, the self-reported leisure time physical activity was lower.

Table 2. Differences in the components of the trans-contextual model

Components of the model	Boys M ± SD	Girls M ± SD
Intention	5.08±1.62	4.63±1.61**
Attitude	5.78±1.03	5.60±1.05*
Perceived behavioural control	5.40±1.29	5.21±1.29
Subjective norms	4.99±1.24	4.96±1.23
Motivation index in PE context	2.25±2.23	1.44±2.35**
Motivation index in leisure time context	5.00±4.82	5.77±4.48*
Autonomy support from PE teacher	4.65±0.93	4.25±1.16**
Autonomy support from peer	4.69±1.17	4.61±1.17
Autonomy support from parent	4.99±1.14	4.94±1.21
Physical activity	4.45±1.28	4.18±1.29**

DISCUSSION

The present study contributes to the extant literature on the trans-contextual model, and the issue of motivational processes underpinning intentional behaviour in general, by introducing additional salient sources of perceived autonomy support to the model. More specifically, this model makes a unique contribution to the literature by specifying the mechanisms by which perceived autonomy support in one context is translated into motivation and behaviour in another. Earlier studies concerning the constructs of trans-contextual model have shown the importance of teachers' autonomy support to autonomous motivation in PE and also highlighted the effect of teachers' autonomy support on autonomous motivation in a leisure-time context [18, 19]. The results of this study confirmed the suitability of the incorporating the peers', parents' and teachers' autonomy support to the model. The perceived autonomy support constructs from additional salient sources, peers and parents, had pervasive effects on the motivational constructs in the extended model. Specifically, these constructs influenced autonomous motivation in a leisure-time context, and surprisingly, the perceived autonomy support from parents had also effect on motivation in PE context. Other interesting finding was that the perceived autonomy support from peers had only indirect effect via intention on physical activity behaviour but not direct effect, whereas perceived autonomy support from PE teachers and parents PE teachers had direct effect.

From the constructs of TBP attitude and PBC were the most important predictors of the intention. The effect of subjective norms to intention was not significant which is consistence with several previous findings [12, 22]. Autonomous motives in leisure time exerted significant, direct effects on attitudes and PBC but not on intention. This result is in accordance with Ajzen's [1] original theory and previous research [17] but inconsistence with later presented trans-contextual models [18, 19] and with other isolated models that have included autonomous motives as a predictor of intentions [4, 40] and have found that a direct effect on intentions also exists beyond the indirect via attitude, subjective norms and behavioural control.

The previous studies based on the SDT in PE context, revealed that the structure of the study measures of the developed models were invariant across gender [25, 31]. Therefore, gender differences in the components of trans-contextual model were found without previous testing for the invariance of the study measures. In this study the boys perceived the autonomy support from teacher significantly more than girls. Ntoumanis [25], who used the short form (LCQ) [39] to measure student perceptions of the autonomy support provided by their PE teachers showed that girls scored a little higher values than boys, however the difference was not statistically significant. Considering the findings reported by Ntoumanis [25] that female students who chose to participant on volitional PE had significantly higher scores in autonomy need satisfaction than females who not chose to participant and that girls felt less autonomy support from teachers than boys in this study, the teachers working with girls have to be more supportive if the aim is to promote physical activity among girls. In terms of practical recommendation based on current results, it is important that teachers in promotion the motivation and leisure time physical activity have to be more autonomously supportive especially in respect of girls.

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DETERMINANTS OF ADULT PHYSICAL ACTIVITY: RELATIVE IMPORTANCE OF YOUTH PHYSICAL ACTIVITY AND DEMOGRAPHIC, PSYCHOLOGICAL, BEHAVIORAL, AND ENVIRONMENTAL FACTORS IN ADULTHOOD

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ABSTRACT

As a part of the longitudinal Cardiovascular Risk in Young Finns Study, the purpose was to examine how adult physical activity is influenced by youth physical activity and current demographic, psychological, behavioral, and environmental factors in 1980. 2309 children and adolescents aged 9, 12, 15 and 18 years were randomly selected from five university towns and their rural surroundings and assessed for physical activity and participation in sports. In 2001, 21 years later, now aged 30, 33, 36, and 39 years, follow-up measurements were performed. Physical activity in 1980 and 2001, and determinants in 2001 were measured through a self-report questionnaire. The results showed that youth physical activity, leadership dimension of Type A behavior, and attention paid to personal health habits were the best predictors of adult physical activity. Education, occupational status, and living environment (urban – rural) were also related to adult physical activity. In women, being married was associated with low physical activity among the younger and high physical activity among the older age-groups. Playing computer games correlated negatively, whereas watching TV correlated positively with physical activity. It was concluded that enhancing youth physical activity plays an important role in the promotion of physical activity and health in the general population.

Key words: physical activity, youth, young adults, determinants, follow-up

INTRODUCTION

The determinants and correlates of physical activity in adults have been widely studied and the factors explaining adult physical activity have been received attention [4, 25, 35], which suggest that adult physical activity is determined by six factors: 1) demographic and biological factors; 2) psychological factors; 3) behavioral attributes; 4) social and cultural factors; 5) physical environmental factors; and 6) physical activity characteristics. Relationships between these factors and physical activity in adults have emerged in cross-sectional studies. However, the determinants of adult physical activity are related more to the multifarious factors than to the single factor [26].

In this study the determinants have been categorized into four groups: demographic, psychological, behavioral, and environmental factors.

Demographic factors

Age is not a determinant of physical activity in this study. Because increasing age in young adulthood brings many life changes such as marriage and having children that influence physical activity, the influence of determinants was studied separately in two age cohorts.

Gender differences in physical activity are well documented in both youth and adulthood. For example, males are more active than females [38]. However, in Finland as in other Nordic countries, gender differences are smaller than in many other countries [29]. There is also a gender difference in the tracking of physical activity, i.e. physical activity tracks better among males than among females [20, 28, 30, 32].

Because one aim of the study was to investigate the influence of youth physical activity on adult physical activity as compared to other determinants in adulthood, gender was controlled for the study. In many cultural environments, high education, occupational status and a higher income mean a higher level of physical activity [4]. On the other hand, to be married and to have children may decrease physical activity as compared being single and not having children [39]. High school sport experience is a better predictor of adult sport involvement than social background factors [7].

Psychological factors

There is evidence that individuals who participate in sport, compared to those who do not, have higher perceived competence, higher self-esteem, more motivation to win, and a more definite achievement goal [24]. Some of these traits are present in Type A behavior which has been investigated [12] in the Young Finns Study, and found [13] that impatience, aggression and hostility were strongly correlated with the later onset of cardiovascular diseases, while leadership-sense of responsibility, including positive self-concept and internal locus of control, was positively associated with maintenance of health. Furthermore, the leadership-sense of responsibility factor, renamed the responsible hard-driving factor, has been found to correlate with sports activities among young people [37, 40]. This is understandable, as physical activity, particularly competitive sport, is goal-oriented and intentional behavior, which requires personal decision-making and a sense of self-efficacy.

Behavioral attributions

The influence of individuals' activity history for their adult physical activity has been shown in longitudinal tracking studies in Finland [22, 28, 33, 34, 39], a consistent finding observed in other studies as well [1, 8, 10, 14, 15, 16, 21, 27, 36]. Sedentary behaviors, such as watching TV and playing computer games have often been seen as reasons for low physical activity level and obesity. A review of the results concerning the relationship between sedentary behaviors, physical activity and obesity concluded that sedentary behaviors do not necessarily displace physical activity, and that there appears to be time for both sedentary behaviors and physical activity among young people [2, 17, 18, 19]. Physical activity has been seen as a part of health behavior because of its relationship with other health habits, e.g. smoking and dieting [4, 22]. This was supported by our previous finding that attention paid to one's health habits correlated with one's physical activity [39].

Environmental factors

The living environment, especially the urban – rural dimension has been found to regulate physical activity and sport participation among both adolescents [38] and young adults [39] in Finland. People living in urban environments are more physically active than those living in rural areas. Physical activity was more dependent on the environment among boys than girls [38].

The aim of this study was to investigate how physical activity at a young age predicts physical activity in adulthood as compared with demographic, psychological, behavioral, and environmental factors in adulthood.

SUBJECTS AND METHODS

The data for this article are drawn from the project Cardiovascular Risk in Young Finns. The epidemiological study consisted of a series of six surveys of six cohorts born in 1962, 1965, 1968, 1971, 1974 and 1977. The ages of the subjects in the cohorts were thus 3, 6, 9, 12, 15 and 18 years in 1980. All the subjects were randomly selected (N = 4320) in the five Finnish university cities with medical schools (Helsinki, Kuopio, Oulu, Tampere and Turku) and their surrounding communities. The same subjects were followed up in 1983, 1986, 1989, 1992 and 2001. The sampling methods used have been discussed in greater detail by Åkerblom et al. [41].

The data for this study cover the four oldest age cohorts (9, 12, 15 and 18 years in 1980). The number of subjects, means and standard deviations of the physical activity index by age group and by gender are shown in Table 1. From this sample, 2309 (1135 boys and 1174 girls) were available and willing to participate in the first study. Twenty-one years later (2001) 1563 (711 males and 852 females) (67.7%) of these subjects participated in the follow-up study, the subjects now aged 30, 33, 36 and 39 years. A frequently encountered methodological problem in longitudinal studies is dropout. Although the number of subjects lost over the twenty-one year period was high, there did not appear to be any differences in the physical activity index at baseline between subjects who remained in the study and those who subsequently dropped out.

Table 1. Numbers (N) and means (M) for physical activity index (PAI) in 1980 of participants (upper figures) and dropouts (lower figures) in 2001 by age and gender

	Males			Females		
	1980	2001		1980	2001	
Age	N	N	M (SD)	N	N	M (SD)
9	309	192	9.9 (1.6)	301	**206**	9.1 (1.5)
		117	9.8 (1.4)		95	9.0 (1.4)
12	312	178	10.0 (1.8)	312	231	8.9 (1.6)
		134	9.9 (1.6)		81	9.2 (1.7)
15	275	186	9.3 (2.0)	297	228	8.3 (1.6)
		89	8.9 (1.9)		69	8.3 (1.6)
18	239	155	8.9 (2.2)	264	187	7.9 (1.5)
		84	9.0 (2.4)		77	8.0 (1.6)
All	1135	711	9.6 (1.9)	1174	852	8.6 (1.6)
		424	9.5 (1.9)		322	8.6 (1.6)

Note: X^2 for categorical variables, Wilcoxon rank score test for continuous variables showed no differences in PAI of 1980 between dropouts and participants in 2001 in any age-gender group.

MEASURES

Physical activity

In 1980, physical activity and participation in sports were measured by means of a short self-report questionnaire administered individually in connection with a medical examination. The questions concerned the frequency and intensity of leisure-time physical activity, participation in sports-club training, participation in competitive sport events, common activity during leisure time, school physical education grades, and type of school commute [31]. A sum index of physical activity (PAI) was computed with the help of these variables. In 2001, leisure-time physical activities were measured by means of the questionnaire according to the following factors: frequency of physical activity, intensity of physical activity, frequency of vigorous physical activity, hours spent on vigorous physical activity, average duration of a physical activity session, and participation in organized physical activity. The original questions of 1980 and 2001 and their scoring for the PAIs are presented elsewhere [32, 33, 34, 38]. The lowest scores indicate passive and the highest scores indicate active.

Cronbach's alpha for the PAI in the 1980 data ranged from 0.49 to 0.76 for males and 0.44 to 0.69 for females. In the 2001 data, Cronbach's alpha for the PAI varied from 0.74 to 0.85 for males and 0.59 to 0.85 for females. Reliability showed a consistent improvement with increasing age. The test-retest reliabilities of the PAIs of the previous years (1980-1992), estimated by the stability coefficients of the simplex-model, were above 0.70 [30]. In the same research project, and in the same sample, a significant negative correlation was found between the PAI and heart rate at rest, serum insulin, and skinfold measurements, which can be seen as an indication of the validity of the activity measure [22].

Demographic variables

A self-report questionnaire was used to measure social, environmental and biological factors in 2001. Place of residence was coded into 1 = rural and 2 = urban. Education was coded into three different levels: 1 = low (comprehensive school), 2 = middle (high school/vocational college), and 3 = high (university). Occupation was divided into three occupational classes: 1 = blue collar (unspecialized and unskilled workers), 2 = lower white collar (civil servants and skilled workers), and 3 = upper white collar (administrators, managers and academics). Marital status was classified into 1 = married (married, engaged, cohabiting) and 2 = non-married (single, divorced, widowed). Number of children was coded into 1 = no child, 2 = one child and 3 = more than one child. Perceived weight was classified into four categories: 1 = underweight, 2 = normal weight, 3 = slightly overweight, and 4 = clearly overweight.

Psychological variables

Type A behavior was measured in 2001 using the Hunter-Wolf A-B Rating Scale [11], which consists of 24 items each ranked on a 7-point scale. Following Ravaja et al. [23], the scale was divided into four dimensions addressing aggression, leadership, responsibility and eagerness-energy. The test-retest correlations of these dimensions have been shown be significant, varying between $r = 0.47$ and $r = 0.66$, aggression and leadership exhibiting the highest stability [23]. In the preliminary analyses, only the leadership factor correlated with physical activity in the adult data, and thus this factor was selected for this study. Individuals scoring high on leadership may be characterized as active, responsible, competitive, and willing to take charge (example items: "I have many hobbies", "I am always a leader in activities", and "I always want to win").

Behavioral variables

The questionnaire in 2001 consisted of the following items: "How much attention do you pay to personal health habits?" The response alternatives were "1 = very much, 2 = much, 3 = hard to say, 4 = little and 5 = very little). Category 5 was combined with category 4 because of the small number of cases. Smoking was indicated on the following scale: 1 = once a day or more often, 2 = once a week, but not daily, 3 = less often than once a week, 4 = trying to give up or giving up, and 5 = never. Those in category 1 were considered smokers and those in categories 2 to 5 were considered non-smokers. Sedentary behaviors were measured by two questions: "Do you watch television daily?" (1 = no, 2 $\leq$ 1 hour, 3 > 1 hour) and "Do you play computer games daily?" (1 = no, 2 = yes).

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS inc., version 12, Chicago, IL) and included the non-parametric Wilcoxon rank score and Kruskal-Wallis tests for continuous variables, and the chi-square test for the categorical variables which were attached to the nominal categories. In order to select the predictor variables, a stepwise multiple regression analysis was performed.

RESULTS

Tables 2 and 3 show the results of cross-tabulation between adult physical activity (PAI) and independent variables. Among men high physical activity in adulthood was significantly related to high physical activity in youth, urban living environment, high education, high occupational status, having no children, high leadership, high attention paid to personal health habits, non-smoking, and perceived normal weight. Marital status and the two sedentary behaviors, watching TV daily and playing computer games, were not related men's physical activity (Table 2). The same variables were related to women's physical activity. Being non-married and not playing computer games were also related to high physical activity in women (Table 3).

Table 2. Distribution (%) of level of men's physical activity by social and health-related behaviour variables

Variable		Level of men's physical activity[1] Low	Moderate	High	p-value[2]
Youth physical activity	Low	47.6	41.3	11.1	
	Middle	33.0	50.7	16.3	
	High	23.4	42.7	33.9	0.001
Place of residence	Rural	35.7	43.3	20.9	
	Urban	24.6	48.2	27.3	0.001
Education	Low	33.1	48.0	18.9	
	Middle	21.2	48.6	30.1	
	High	19.4	44.8	35.8	0.001
Occupation	Blue collar	41.2	32.4	26.5	
	Lower white collar	34.2	46.6	19.2	
	Upper white collar	21.6	48.0	30.3	0.001
Marital status	Married	29.1	47.1	23.8	
	Non-married	26.3	44.0	29.7	n.s.
Having children	No child	23.2	46.8	30.0	
	One child	32.6	47.2	20.2	
	> One child	35.0	44.0	21.0	0.001
Leadership dimension of					
Type A behaviour	Low	40.3	52.0	7.7	
	Middle	29.7	44.9	25.4	
	High	15.5	41.1	43.4	0.001
Attention paid to personal					
health habits	Hardly at all	44.3	43.3	12.5	
	Hard to say	33.4	48.1	18.5	
	Much	15.5	50.7	33.8	
	Very much	15.8	14.0	70.2	0.001
Smoking	Smoker	40.4	43.8	15.8	
	Non-smoker	23.3	46.9	29.7	0.001
Perceived weight	Underweight	43.9	48.8	7.3	
	Normal weight	25.3	43.6	31.2	
	Slightly overweight	28.5	48.6	23.0	
	Clearly overweight	39.6	49.0	11.5	0.001
Watching TV daily	No	38.6	47.7	13.6	
	≤ 1 hour	28.8	45.3	26.0	
	> 1 hour	27.1	46.7	26.2	n.s.
Playing computer games daily	No	28.0	47.4	24.7	
	Yes	28.3	40.4	31.4	n.s.

[1] Level of men's physical activity (PAI of 2001) was divided into three categories: 5–7 = Low, 8–10 = Moderate and 11–14 = High

[2] Chi-square test

Table 3. Distribution (%) of level of women's physical activity by social and health-related behaviour variables

Variable		Level of women's physical activity[1] Low	Moderate	High	p-value[2]
Youth physical activity	Low	33.6	53.0	13.4	
	Middle	28.6	53.4	18.0	
	High	13.2	56.9	29.9	0.001
Place of residence	Rural	29.2	56.0	14.8	
	Urban	21.1	52.7	26.2	0.001
Education	Low	29.4	55.3	15.3	
	Middle	25.2	51.4	23.4	
	High	12.6	57.6	29.8	0.001
Occupation	Blue collar	32.2	53.1	14.7	
	Lower white collar	27.7	56.3	16.0	
	Upper white collar	20.2	54.3	25.6	0.01
Marital status	Married	26.0	54.4	19.6	
	Non-married	19.7	52.2	28.1	0.001
Having children	No child	17.4	53.5	29.1	
	One child	28.0	53.3	18.7	
	> One child	29.3	54.2	16.5	0.001
Leadership dimension of Type A behaviour	Low	33.4	53.1	13.5	
	Middle	17.4	58.6	24.0	
	High	11.6	53.1	35.3	0.001
Attention paid to personal health habits	Hardly at all	45.1	48.4	6.5	
	Hard to say	38.1	50.4	11.5	
	Much	16.9	58.6	24.5	
	Very much	11.0	42.5	46.5	0.001
Smoking	Smoker	37.3	46.7	16.1	
	Non-smoker	20.9	55.5	23.6	0.001
Perceived weight	Underweight	50.5	35.0	15.0	
	Normal weight	19.9	54.7	25.4	
	Slightly overweight	26.5	54.4	19.2	
	Clearly overweight	32.6	51.6	15.8	0.001
Watching TV daily	No	25.0	54.4	20.6	
	≤ 1 hour	23.5	53.4	23.1	
	> 1 hour	24.2	54.0	21.8	n.s.
Playing computer games daily	No	23.1	53.9	23.0	
	Yes	40.3	48.1	11.7	0.001

[1] Level of women's physical activity (PAI of 2001) was divided into three categories: 5–7 = Low, 8–10 = Moderate and 11–14 – High

[2] Chi-square test

Table 4. Correlations between all variables among men and women

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Youth physical activity	-	.31**	.24**	.09*	.01	.10*	.07	.06	.02	-.11**	.01	-.01	.01
2. Adult physical activity	.18**	-	.35**	.35**	.13**	.19**	.18**	-.06	-.15**	-.19**	.09*	.04	-.10**
3. Leadership	.15**	32**	-	.18**	.10*	.16**	.21**	.11**	.02	-.06	-.08*	.03	.02
4.Attention paid to personal health habits	.08	.33**	.23**	-	.16**	.21**	.11**	-.06	-.09*	-.27**	-.05	-.02	-.14**
5. Place of residence	.05	.12**	.09*	.13**	-	.27**	.24**	-.08	-.15**	-.09*	.10*	.05	-.07
6. Education	.12**	.14**	.25**	.15**	.20**	-	.59**	.03	-.08*	-.30**	-.08*	.01	-.04
7. Occupation	.05	.13**	.20**	.11**	.13**	.43**	-	.06	-.03	-.19**	-.03	-.02	.03
8. Marital status	.05	-.06	-.06	-.05	-.22**	-.06	.05	-	.48**	-.04	-.08*	-.01	.14**
9. Having children	-.06	-.16**	-.15**	-.09*	-.22**	-.16**	-.11**	.44**	-	-.01	-.11**	-.09*	.15**
10. Smoking	-.01	-.13**	-.16**	-.21**	-.01	-.25**	-.16**	-.13**	-.02	-	-.07	-.06	.04
11. Watching TV daily	-.06	.01	-.12**	-.07	-.03	-.19**	-.12**	-.03	-.09*	-.13**	-	.09*	.04
12. Playing computer games daily	-.05	-.10*	-.04	-.03	.03	-.02	-.04	.01	-.06	-.10*	.05	-	.04
13. Perceived weight	-.02	-.13**	-.07	-.20**	11**	-.10*	-.02	.07	.09*	-.05	11**	.09*	-

Note: Figures for women are given in the lower diagonal (left), for men in the upper diagonal (right). * p<.05, ** p<.01

Table 4 shows the intercorrelations of the determinants. The best predictors of physical activity, leadership and attention paid to personal health habits, also correlated significantly with many other determinants.

Because age and gender correlated with most of the variables, stepwise multiple regression analyses with adult physical activity as the dependent variable were carried out in two age-gender groups (Table 5). Leadership, attention paid to personal health habits and youth physical activity were the best predictors of adult physical activity in all the age-gender groups. Women's physical activity was also predicted by high occupational status, playing no computer games and being non-married. Among both sexes, those who watched television daily showed a higher level of physical activity than those who did not. Together, the predictors in the equation accounted for 20–37% of the variation in adult physical activity in the age-gender groups.

Table 5. Regression (stepwise) of adult physical activity on all variables by two age-gender groups

Age-gender group	Rank Variables	R	R^2	r	Beta	F
30- and 33-year-old women						
	1. Leadership			.45	.30	22.81***
	2. Attention paid to personal health habits			.41	.30	24.00***
	3. Occupation			.20	.15	6.81**
	4. Playing computer games daily			-.19	-.17	7.62**
	5. Youth physical activity			.21	.16	6.65 *
	6. Marital status	.61	.37	-.14	-.14	5.39*
30- and 33-year-old men						
	1. Attention paid to personal health habits			.48	.37	23.37***
	2. Youth physical activity			.33	.21	8.12**
	3. Leadership	.56	.32	.36	.20	7.31**
36- and 39-year-old women						
	1. Attention paid to personal health habits			.33	.29	20.84***
	2. Leadership			.27	.19	8.47**
	3. Playing computer games daily			-.15	-.15	5.64*
	4. Watching TV daily			.11	.17	7.60**
	5. Youth physical activity			.23	.14	5.16*
	6. Marital status	.48	.23	.13	.13	4.19*
36- and 39-year-old men						
	1. Youth physical activity			.26	.24	8.35***
	2. Attention paid to personal health habits			.25	.26	10.23***
	3. Leadership			.22	.19	5.02*
	4. Watching TV daily	.45	.20	.19	.18	4.56*

*p < .05,**p < .01 and ***p < .001.

DISCUSSION

The purpose of this study was to examine the determinants of adult physical activity, and in particular, influence of youth physical activity as compared to other determinants. The results revealed that the most powerful determinants were the leadership factor of Type A behaviour and attention paid to personal health habits. In addition, youth physical activity was an important determinant. These three variables were accepted in the regression model in all four age-gender groups showing that they are important correlates of adult physical activity.

The findings of the study showed that adult physical activity was significantly predicted by a high level of leadership in all the age-gender groups. The results were consistent with our previous findings [37] that leadership (then called responsible hard-driving) explained physical activity among both adolescents and young adults. The results also confirm the view that psychological characteristics, in particular those connected with self-efficacy and self-determination are important determinants of physical activity [5, 35]. As leadership as a personality trait indicates high self-esteem, high achievement motivation and internal locus of control, it is possible that people who have a high level of leadership tend to have positive attitudes, beliefs and values with respect to physical activity. Our finding supports in part the earlier conclusion by Dishman [9] that physically active adults are significantly more often Type A personalities than their counterparts, but the present study is more specific in indicating that in particular the "protective" dimension [13] of Type A behavior correlates positively with physical activity.

In sum, our findings show that personality and attitudes towards health behaviors are strong determinants of physical activity. It is known that personality characteristics are rather stable over the life-course and that health-related attitudes are formed rather early in life [6]. Thus, our findings imply that in order to increase the level of physical activity across the whole population, sport-positive attitudes and experiences should be acquired relatively early in life.

Both the cross-tabulation and regression analysis showed that the health-related variable: "attention paid to personal health habits" was the best predictor of adult physical activity, as was also the case in our 12-year follow-up study [39]. The predictive power of this variable was shown by the cross-tabulation result according to which only 12% of those men who paid hardly any attention to their health behavior were among the highest tertile in amount and intensity of physical activity, as against 70% of those who reported paying a great of attention to their health (Table 2). It suggests that people perceive physical activity as a part of health behavior. This was supported by the finding that smoking correlated negatively with physical activity and that high physical activity was associated with normal weight. It is possible that physical activity increases awareness of the body and its functions and may lead people to pay more attention, for example, to dietary habits and weight control. People are motivated to be physically active because of its health effects. However, it seems that the association between physical activity, health and health behavior is more complicated than just a simple one-way causal relationship. It may be that the relationship between health and physical activity is reversible, as suggested by Bouchard and Shepard [3].

The result that youth physical activity significantly predicted adult physical activity has been found in many previous studies [1, 10, 14, 28, 32, 33, 34, 36]. In the present study the influence of youth physical activity was compared with other determinants of adult physical activity at 21 years interval. We did this for the first time in our 12-year longitudinal study of the same subjects, then aged 21 - 30 years [39]. The results were same in both studies, indicating that adult physical activity appears to be more influenced by youth physical activity than by such social and environmental factors as education, occupation, marital status, number of children and living environment. The same result was found in a retrospective study by Curtis, McTeer & White [7]. Only leadership and attention paid to personal health habits were stronger predictors. This result emphasizes the importance of enhancing young people's interest in physical activity when the aim is the promotion of physical activity and health among the population as a whole.

Demographic and environmental variables, education, occupation, and living environment (urban – rural) correlated to physical activity in both genders as found in several previous studies [5, 35]. Due to intercorrelations of the determinants only occupation was accepted in the regression model yielding the best predictors and only among 30 to 33-year-old women. However, a person's social status, indicated here by education and occupational status, may still regulate physical activity to a certain degree, for instance through attention paid to personal health habits. The correlation between education and attention paid to personal health habits was significant. It may be that for educated people it is easier to adopt healthy habits.

The relationship between marital status and physical activity showed both gender and age differences. Marital status only affected women's physical activity, but differently in two age groups. In the younger group being married meant less physical activity while in older group married women participated more in physical activity than their unmarried counterparts. This can be understood if the age of children is taken into account. It may be that 30 to 33-year-old women still have very young children and thus limit their participation in physical activities, or that they do not consider being outdoors with babies as physical activity. Older women probably have children who are able to participate in same activities as their mothers. Although Finnish men share domestic chores in the family to a certain degree and this has increased over last few decades, women are still mainly responsible for children, which can be seen in the decreased level of physical activity among women with children.

Sedentary behaviors such as watching TV daily and playing computer games have been commonly seen as reasons for low engagement in physical activity. In women, playing computer games was one of the strongest predictors of a lack of physical activity in both age groups. In men, playing computer games did not correlate with physical activity. At the level of the whole sample, watching TV did not correlate with physical activity in either women or in men. However, in the older groups of women and men it was among the best, positive, predictors of physical activity. This result is consistent with previous findings according to which sedentary behavior is not the negative end of the physical activity continuum, and that active people have time for both physical activity and sedentary behavior [2, 17, 18, 19].

CONCLUSION

Youth physical activity, personality characteristics, and health-related attitudes play an important role in determining adult physical activity at the age of 30–39 years. In seeking to promote of physical activity in the general population emphasis should be laid on stimulating interest in physical activity among children and adolescents. Because physical activity is perceived as a part of health behavior, the current health-related approach to encouraging physical activity among the adult population seems to be appropriate. Although the influence of social status on physical activity is not as strong as, for example, the influence of physical activity in youth, it is a significant determinant which should be taken into account in efforts to promote increased physical activity. A one-sided focus on computer games may reduce physical activity, but other sedentary behaviors, such as watching TV, do not displace physical activity, as active people seem to have time both physical activity and sedentary pastimes.

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