ACTA KINESIOLOGIAE UNIVERSITATIS TARTUENSIS

VOLUME 9

ACTA KINESIOLOGIAE UNIVERSITATIS TARTUENSIS

9

UNIVERSITY OF TARTU

ACTA KINESIOLOGIAE UNIVERSITATIS TARTUENSIS

VOLUME 9

TARTU 2004

This journal is indexed in: Sport Discus Database

Tartu University Press
www.tyk.ut.ee
Order No. 590

CONTENTS

THE EFFECTS OF WARM UP ON INTERMITTENT-SPRINT PERFORMANCE

D. Bishop, B. Claudius
Team Sport Research Group
School of Human Movement and Exercise Science
The University of Western Australia, Australia

ABSTRACT

We assessed the effects of warm up on intermittent-sprint performance. In a random order, subjects performed an intermittent-sprint test (IST; two 36-min 'halves' of repeated ~2-min blocks; all-out 4-s sprint, 100 s at 35% $\dot{V}O_{2peak}$, 20-s rest) after either no warm up (CON) or 10-min warm up (WUP). WUP consisted of 5 min at 50% of $\dot{V}O_{2peak}$, followed by two 30-s bouts at 70% $\dot{V}O_{2peak}$ interspersed with 30-s rest, and then a 2-min block of the IST followed by 1 min at 35% $\dot{V}O_{2peak}$ and 2-min rest. Pre test (post warm up) [La] was higher in WUP than CON, but not significantly different at any other time point. There was no significant difference in total work or peak power between CON and WUP during either half of the IST. While previous studies have reported increases in single-sprint performance following warm up, it is important to note that peak power occurred at sprint 6 of the IST. Therefore, the effects of the warm up may have been masked by the warm up effect of the initial sprints or as a result of pacing. Thus, while warm up may improve single-sprint performance, it did not improve intermittent-sprint performance in the present study.

Key words: plasma lactate, cycling, intermittent exercise, peak power

INTRODUCTION

Despite limited scientific evidence supporting its effectiveness, warm-up routines prior to exercise are a well-accepted practice by most coaches and athletes. The majority of the effects of warm up have been attributed to temperature-related mechanisms [4]. An increase in muscle temperature (T_{mu}) following active warm up has the potential to improve short-term performance in many ways. An increase in T_{mu} has been reported to decrease the stiffness of muscles and joints [8, 30], increase the transmission rate of nerve impulses [18], change the force-velocity relationship [3, 9, 25] and to increase glycogenolysis, glycolysis and high-energy phosphate degradation [12, 13]. Active warm up may also have additional effects on decreasing muscle stiffness by 'breaking' the stable bonds between actin and myosin filaments [23].

While the majority of studies have reported that active warm up improves single-sprint performance [11, 16, 20, 22, 26, 28], a few studies have reported either no significant effect [10,17] or impaired single-sprint performance [19, 26] following active warm up. However, in the relatively few studies where active warm up has been reported not to significantly improve single-sprint performance, it appears that the warm up was either too easy (to sufficiently raise T_{mu}) or too intense (resulting in decreased availability of high-energy phosphates). It appears therefore, that a moderate-intensity warm up is likely to significantly improve single-sprint performance.

In contrast to the many studies that have investigated the effects of warm up on single-sprint performance, to date, no study has investigated the effects of warm up on intermittent-sprint performance. This is surprising as in most countries the most popular sports and those with the highest participation levels are team games (that require athletes to sprint intermittently throughout a match). The purpose of the present study therefore, was to investigate the effects of warm up on intermittent-sprint performance. The intermittent-sprint test (IST) was based on a motion analysis of international field hockey and consisted of short-duration sprints interspersed with periods of active and passive recovery [27]. It was hypothesised that warm up would enhance performance during the prolonged IST.

METHODS

Subjects

Seven female, team-sport athletes were recruited to participate in this study (mean ± SD: age 19 ± 1 y, mass 58.0 ± 1.6 kg, $\dot{V}O_{2peak}$ 45.3 ± 3.0 $mL \cdot kg^{-1} \cdot min^{-1}$). Subjects were informed of the study requirements, benefits and risks before giving written informed consent. Approval for the study's procedures was granted by the institutional Research Ethics Committee.

Experimental overview

In addition to a familiarisation session for all tests, the main experiment required the subjects to be tested on three separate occasions. On day one, subjects performed a graded exercise test (GXT) to determine $\dot{V}O_{2peak}$. At least 48 h later. in a random, counterbalanced order, subjects then performed the intermittent-sprint test (IST), following either no warm up (CON) or warm up (WUP). A week separated the two IST testing sessions and both IST tests were conducted at the same time of day to control for diurnal effects. Capillary blood was sampled prior to and during each IST. Subjects were asked to maintain their normal diet and training throughout the study. Before every testing session, subjects were required to consume no food or beverages (other than water) two hours prior to testing and were asked not to consume alcohol or perform vigorous exercise in the 24 h prior to testing. The ambient room temperature was maintained at 22.0 ± 1.0°C and relative humidity 50 ± 10% for all tests.

Ergometers

Air-braked cycle ergometers were used to conduct all cycle tests. These ergometers were interfaced with an IBM-compatible computer system to allow for the collection of data for the calculation of work and power generated during each flywheel revolution (Cyclemax, The University of Western Australia, Perth, Australia). These ergometers require subjects to pedal against air resistance caused by rectangular vanes attached perpendicular to the axis of rotation of the flywheel. The power output of the air-braked cycle ergometer is proportional to the cube of the flywheel velocity. An optical sensor monitored the velocity of the flywheel at a sampling rate of 80 pulses per pedal revolution. Before testing, each ergometer was dynamically calibrated on a mechanical rig (Western Australian Institute of Sport, Perth, Australia) across a range of power outputs (100–2000 W).

Graded exercise test

The GXT was performed on an air-braked, track-cycle ergometer (Evolution Pty. Ltd., Adelaide, Australia) and consisted of graded exercise steps (3-min stages), using an intermittent protocol (1-min break between stages). The test commenced at 40 W and thereafter, intensity was increased by 30 W every 3 min until volitional exhaustion. Subjects were required to maintain the set power output, which was displayed on a computer screen in front of them. The test was stopped when the subject could no longer maintain the required power output. Strong verbal encouragement was provided to each subject as they came to the end of the test.

Intermittent-sprint test (IST)

Based on a motion analysis study of international field hockey [27], the intermittent-sprint test (IST) was designed to mimic the average sprint profile of a typical team-sport game and consisted of 36-min of intermittent-sprint exercise (Figure 1). The protocol was divided into ~2-min blocks of sprinting, active recovery and passive rest. Each 2-min block started with an all-out 4-s sprint immediately followed by 100 s of active recovery. The active recovery required the subject to maintain a constant power output of 35% of their pre-determined power output at $\dot{V}O_{2peak}$. The 2-min block was then completed by 20 s of passive rest. On two occasions during each 36-min half (following sprints 8 & 16), a repeated-sprint bout (RSB) comprising five, 2-s sprints departing every 20 s with active recovery between subsequent 2-s sprints, replaced the 2 min of active and passive recovery. Each treatment condition required the subject to perform two halves of the simulated team-sport game. The subjects were given 10-min passive recovery between ‘halves’.

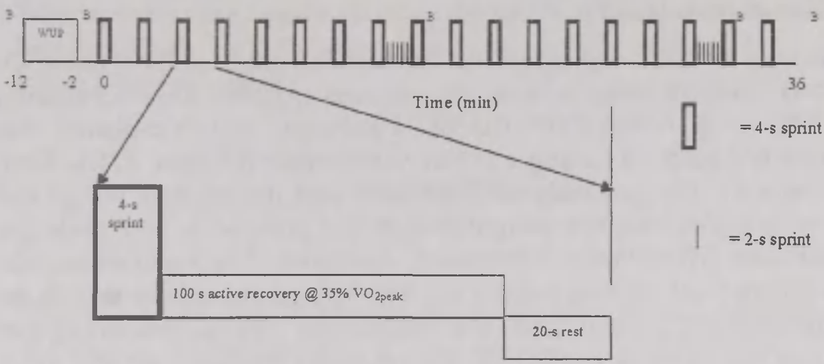

Figure 1. Schematic representation of the first half of the repeated-sprint test (top section). Each ~ 2-min block comprised a 4-s maximal sprint, 100 s at 35% VO_{2peak} and 20-s passive rest (botom section). There were also two repeated-sprint bouts which comprised five, 2-s sprints separated by ~ 20 s at 35% VO_{2peak}. WUP=warm up, B=blood sample.

Twelve minutes prior to the beginning of the IST, subjects in the CON group were seated on the cycle ergometer and subjects in the WUP group completed a 10-min warm-up on the front-access ergometer (Model Ex-10, Repco, Australia). The warm-up required the subjects to cycle for 5 min at 50% of their predetermined $\dot{V}O_{2peak}$, followed by two blocks of 30 s at 70% $\dot{V}O_{2peak}$ interspersed with 30-s rest. The subjects then performed a practice 2-min block of the IST protocol followed by 1 min of gentle cycling. The subjects then rested and the IST started 2 min after the completion of the warm-up. While the IST was performed on the front-access cycle ergometer, it has been reported that repeated-sprint cycling performance on the front-access cycle ergometer is strongly correlated with repeated-sprint running performance [7]. To further enhance the relevance of this study, all sprints were performed in the standing position on the front-access cycle ergometer. The subjects were provided with standardised amounts of water (3 × 150 mL) and carbohydrate solution (3 × 150 mL) at regular intervals (~ every 15 min) during every IST to ensure they were adequately hydrated.

Gas analysis (GXT)

During the GXT, expired air was continuously analysed for O_2 and CO_2 concentrations using Ametek gas analysers (Applied Electrochemistry, SOV S-3A11 and COV CD-3A, Pittsburgh, PA). Ventilation was recorded every 15 s using a turbine ventilometer (Morgan, 225A, Kent, England). The gas analysers were calibrated immediately before and verified after each test using three certified gravimetric beta-grade gas mixtures (BOC Gases, Chatswood, Australia). The ventilometer was calibrated pre-exercise using a one litre syringe in accordance with the manufacturer's instructions. The ventilometer and gas analysis system were connected to an IBM PC that measured displayed variable every 15 s.

Capillary blood sampling and analysis

Glass capillary tubes were used to collect 35 μL of blood during the GXT (D957G-70-35, Clinitubes, Radiometer Copenhagen) and 125 μL of blood during the intermittent sprint exercise test (D957G-70-125, Clinitubes, Radiometer Copenhagen). Capillary blood samples were taken at rest and immediately following each 3-min stage of the GXT. Capillary blood samples were also taken before and after the warm up, and before and after each half of the IST. In addition, blood was sampled during the active recovery following the ninth and seventeenth 4-s sprint (following the 5, 2-s repeated sprint bout) of the IST (Figure 1). Capillary blood was analyzed for lactate concentration. The blood-gas analyzer (ABL 625, Radiometer Copenhagen) was regularly calibrated using precision standards and routinely assessed by external quality controls.

Statistical analysis

All values are reported as mean ± SE_M. Two-way ANOVA (2 treatments × 18 sprints) with repeated measures were used to determine whether there were any performance differences between each half of the IST. Similarly, two-way ANOVA (2 treatments × 9 measurements) with repeated measures were used to determine whether the blood data collected over the duration of each IST test, differed across conditions.

Where appropriate, post-hoc comparisons were employed (Student-Newman-Keuls test). Statistical significance was accepted at $P < 0.05$ unless otherwise stated.

RESULTS

Blood

Plasma [La⁻] for both conditions, across all time points is summarised in Figure 2. Pre test plasma [La⁻] was significantly higher in the WUP group than the CON group (P=0.02). Plasma [La⁻] was not significantly different between the two groups at any other time point.

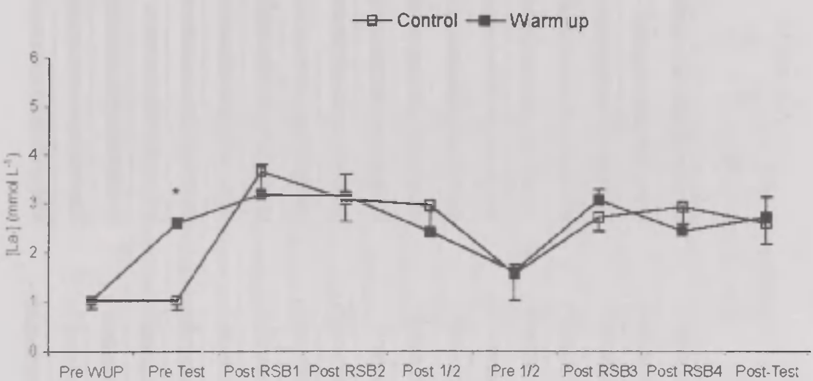

Figure 2. Plasma lactate concentration ([La⁻] for the control and warm up conditions. Values are mean ± SE_M (n = 7). * Indicates a significant difference from control condition (p < 0.05). Legend: WUP = warm up, RSB = repeated-sprint bout, ½ = first 'half' of intermittent-sprint test.

Performance data

There was no significant difference in the total work completed between the CON and WUP condition during the first half (34554.2 ±

5827.4 v 35588.5 ± 4549.7 J; P=0.72) or second half (34269.8 ± 5138.6 v 35986.8 ± 4702.8 J; P=0.41). The average amount of work performed by participants during individual sprints in each half of the IST is summarised in Figure 3. There were also no significant differences in peak power between conditions during the first half (745.2 ± 116.9 v 749.6 ± 84.5 W; P=0.93) or second half (727.1 ± 107.5 v 763.8 ± 136.2 W; P=0.12) of the IST. The average peak power achieved by participants during individual sprints of each half of the IST is summarised in Figure 4.

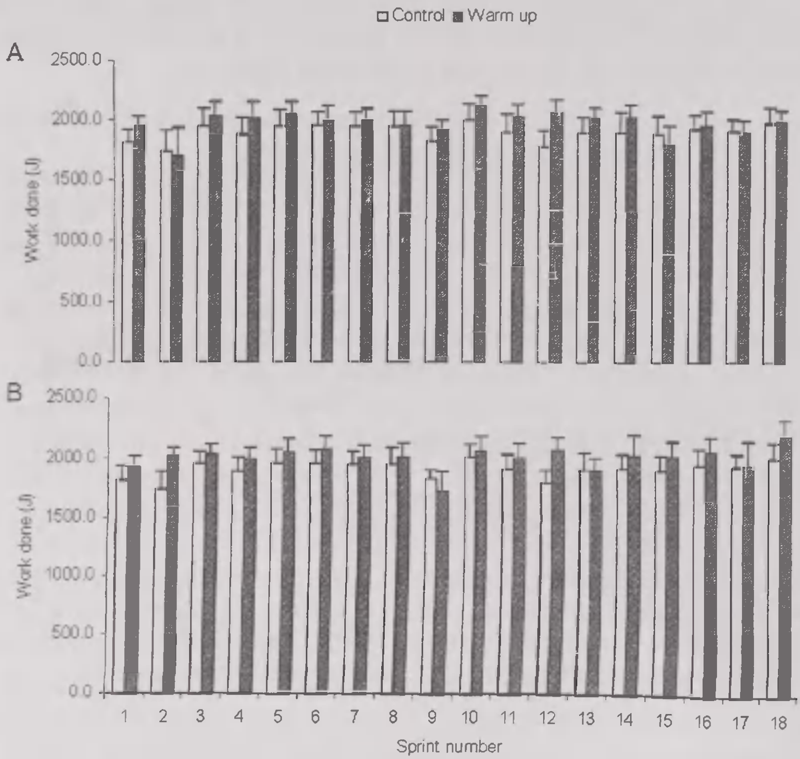

Figure 3. Work completed (J) during individual sprints in the first half (A) and second half (B) of the intermittent-sprint test for the CON and WUP condition. Values are mean ± SE_M (n=7).

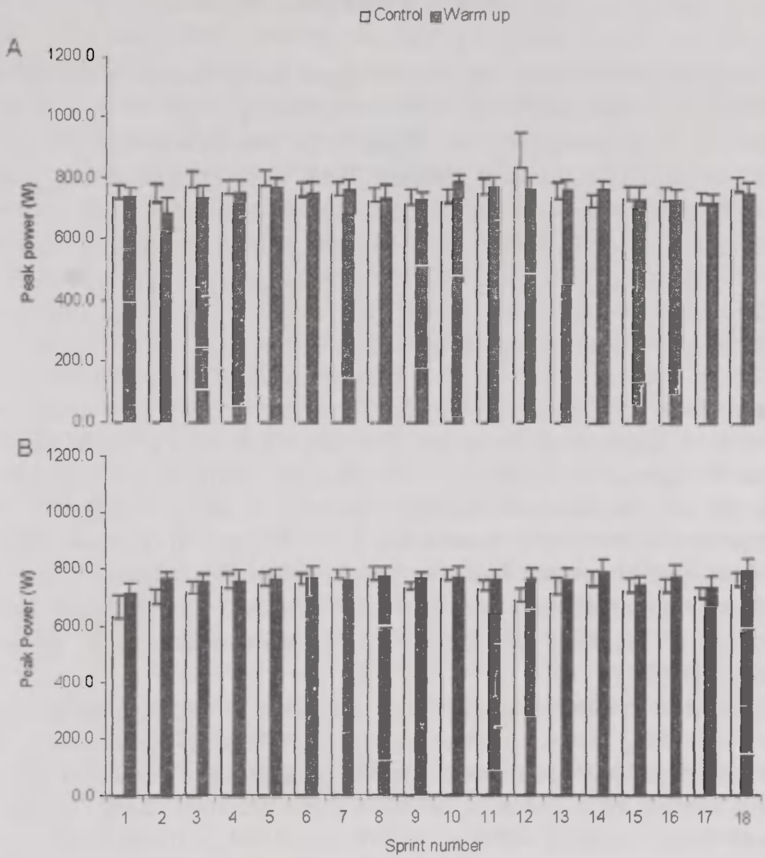

Figure 4. Peak power achieved (W) during individual sprints in the first half (A) and second half (B) of the intermittent-sprint test for the CON and WUP condition. Values are mean ± SE_M (n=7).

DISCUSSION

The purpose of this study was to investigate the effects of warm up on intermittent-sprint performance. The main finding of this study was that prior exercise (warm up) did not improve the intermittent-sprint performance of trained, team-sport athletes. Total work completed and average peak power were not significantly different between conditions in either half of the IST. These results challenge the conventional wisdom that warm up is important to optimise intermittent-sprint performance.

A number of studies have previously reported significant increases in single-sprint performance following warm up [11, 20, 26]. This improvement appears to be largely, although not entirely, attributable to an increase in T_{mu}. An increase in T_{mu} following active warm up has the potential to improve single-sprint performance in many ways. An increase in T_{mu} has been reported to decrease the stiffness of muscles and joints [8, 30], increase the transmission rate of nerve impulses [18], change the force-velocity relationship [3, 9, 25] and to increase glycogenolysis, glycolysis and high-energy phosphate degradation [12, 13]. Active warm up may also have additional effects on decreasing muscle stiffness by 'breaking' the stable bonds between actin and myosin filaments [23].

In contrast to reports of significant increases in single-sprint performance following warm up, there was no significant effect of warm up on intermittent-sprint performance in the present study. However, there were a number of differences between these previous studies and the present study. Previous warm up studies employed performance tests of 10–20 s [11, 20, 26], whereas the repeated sprints in the present study were only 4 s in duration. However, this is unlikely to explain the contradictory results as peak power should occur in the first 4 s [2]. Furthermore, active warm up has been reported to improve short-term power output (vertical jump height and vertical jump power; [14, 22]). Thus, it appears unlikely that differences in sprint duration can explain the absence of a significant effect of warm up on intermittent-sprint performance in the present study.

The most important difference between the present and previous studies is that this is the first study to investigate the effects of warm up on intermittent-sprint performance. It is important to note that in addition to the prescribed warm up, the first few sprints in the present study would also have served as a warm up. As such, peak power never occurred on sprint 1, but instead occurred on average at sprint 6. Maximal dynamic exercise (knee extensions) has previously been reported to result in an increased twitch potentiation during subsequent exercise [15]. This potentiation has been attributed to phosphorylation of the light chains on the myosin head [21] and/or elevation of Ca^{2+} in the cytosol [1]. It is therefore, possible that the large voluntary contractions required for the initial sprints may have improved peak power output similarly in both conditions during the IST via an increase in voluntary neuromuscular activation.

If the first few sprints of the present study provided a warm up stimulus in both conditions, this may have contributed to the absence of a significant difference in the total work completed between the CON and WUP conditions. As a result, small differences in the first few sprints of the WUP condition may not have been great enough to influence the total work score which was calculated as the sum of the 18 sprints performed in each half. Therefore, the effects of the warm up on performance may have been masked by the warm up effect of the initial sprints and this may partially explain why warm up had no significant effect on the intermittent-sprint performance of trained, team-sport athletes in the present study.

While there are a number of possible explanations as to why warm up did not improve intermittent-sprint performance, it is more difficult to explain why warm up did not improve initial sprint performance. As previously mentioned, the majority of previous studies have reported that active warm up improves single-sprint performance [11, 16, 20, 22, 26, 28]. However, differences in warm up intensity, or the use of a pacing strategy, may explain why warm up did not improve initial sprint performance in the present study.

The ability to produce a high power output decreases rapidly during repeated, all-out, sprint exercise (interspersed with short rest periods) and is related to the power output of the first sprint [6]. Therefore, in order to sustain a high power output during the intermittent-sprint test in the present study, athletes may have adopted a pacing strategy — where pacing strategy is defined as the conscious or subconscious regulation of work and power output in order to maximise performance. It has previously been proposed that a subconscious "controller" determines the overall pacing strategy during exercise by matching the rate of energy expenditure and the current energy reserves with the predicted energy cost of the exercise [29]. Furthermore, this "controller" considers the duration of the planned effort and calculates the pacing strategy on the basis of previous experience. Thus, the use of a pacing strategy may not have allowed the full benefits of the warm up on initial sprint performance to have been realised during the intermittent-sprint test in the present study.

An alternative explanation is that the warm up protocol used in the present study was not appropriate to improve sprint performance. It has previously been reported that a low-intensity warm up consisting of calisthenics or a few practice trials does not significantly improve sprint performance [10,24]. However, the warm up protocol used in the present study (5 min at 50% $\dot{V}O_{2peak}$, followed by two blocks of 30 s at 70% $\dot{V}O_{2peak}$ followed by 30-s rest and a 2-min block of the IST) was of equal or greater intensity to warm up protocols that have been previously reported to improve sprint performance [5]. Alternatively, the warm up may have been too intense and/or there was insufficient recovery between the active warm up and the IST. Hawley et al. [17] argued that cycle peak power was not improved in their study as the untrained subjects were fatiguing themselves during the warm up (8-min incremental test). However, it appears unlikely that the present warm up was too intense as the plasma lactate concentration at the start of the IST was only 2.6 ± 1.3 mmol · L^{-1} (Figure 2.). Thus, it appears unlikely that the absence of a significant improvement in IST performance in the present study can be attributed to a warm up protocol that was either too easy or too intense.

In summary, the main findings of this study were that prior exercise (warm up) did not improve initial sprint performance, or intermittent-sprint performance (work completed or peak power output) of trained, team-sport athletes. While previous studies have reported significant increases in single-sprint performance following warm up, it is important to note that peak power occurred on average at sprint 6 of the IST in the present study. Therefore, the effects of the warm up may have been masked by the warm up effect of the initial sprints. Furthermore, the use of a pacing strategy may have not allowed the full benefits of the warm up on initial sprint performance to have been realised during the intermittent-sprint test in the present study. As this is the first study to investigate the effects of warm up on intermittent-sprint performance, further research is required to replicate these findings.

REFERENCES

1. Allen D. G., Lee J. A., Westerblad H. (1989) Intracellular calcium and tension during fatigue in isolated single muscle fibres from xenopus laevis. J. Physiol. 415: 433–458
2. Bergh U., Ekblom B. (1979) Influence of muscle temperature on maximal muscle strength and power output in human skeletal muscles. Acta Physiol. Scand. 107: 33–37
3. Binkhorst R. A., Hoofd L., Vissers A. C. A. (1977) Temperature and force-velocity relationship of human muscles. J. Appl. Physiol. 42: 471–475
4. Bishop D. (2003) Warm up I: Potential mechanisms and the effects of passive warm up on exercise performance. Sports Med. 33: 439–454
5. Bishop D. (2003) Warm up II: Performance changes following active warm up and how to structure the warm up. Sports Med. 33: 483–498
6. Bishop D., Lawrence S., Spencer M. (2003) Predictors of repeated-sprint ability in elite female hockey players. J. Sci. Med. Sport. 6: 199–209
7. Bishop D., Spencer M., Duffield R., and Lawrence S. (2001) The validity of a repeated sprint ability test. J. Sci. Med. Sport. 4: 19–29
8. Buchthal F., Kaiser E., Knappeis G. G. (1944) Elasticity, viscosity and plasticity in the cross striated muscle fibre. Acta Physiol. Scand. 8: 16–37
9. Davies C. T. M., Young K. (1983) Effect of temperature on the contractile properties and muscle power of triceps surae in humans. J. Appl. Physiol. 55: 191–195
10. De Vries H. A. (1959) Effects of various warm-up procedures on 100-yard times of competitive swimmers. Res. Q. Exerc. Sport. 30: 11–22

11. Dolan P., Greig C., Sargeant A. J. (1985) Effect of active and passive warm-up on maximal short-term power output of human muscle. J. Physiol. 365: P74
12. Edwards R. H. T., Harris R. C., Hultman E., Kaisjer L., Koh D., Nordesjo L. D. (1972) Effect of temperature on muscle energy metabolism and endurance during successive isometric contractions, sustained to fatigue, of the quadriceps muscle in man. J. Physiol. 220: 335–352
13. Febbraio M. A., Carey M. F., Snow R. J., Stathis C. G., Hargreaves M. (1996) Influence of elevated muscle temperature on metabolism during intense, dynamic exercise. Am. J. Physiol. 271: R1251–R1255
14. Goodwin J. E. (2002) A comparison of massage and sub-maximal exercise as warm-up protocols combined with a stretch for vertical jump performance. J. Sports Sci. 20: 48–49
15. Gossen E. R., Sale D. G. (2000) Effect of postactivation potentiation on dynamic knee extension performance. Eur. J. Appl. Physiol. 83: 524–530
16. Grodjinovsky A., Magel J. R. (1970) Effect of warming-up on running performance. Res. Q. Exerc. Sport. 41: 116–119
17. Hawley J. A., Williams M. M, Hamling G. C., Walsh R. M. (1989) Effects of a task-specific warm-up on anaerobic power. Br. J. Sports Med. 23: 233–236
18. Karvonen J. (1992) Importance of warm up and cool down on exercise performance. In: Medicine and Sports Science. Medicine and sports training and coaching, J. Karvonen, P. W. R. Lemon, and I. Iliev (Eds.). Basel: Karger, pp. 190–213
19. Margaria R., DI Prampero P.E., Aghemo P., Derevenco P., Mariani M. (1971) Effect of a steady-state exercise on maximal anaerobic power in man. J. Appl. Physiol. 30: 885–889
20. McKenna M. J., Green R. A., Shaw P. F., Meyer A. D. (1987) Tests of anaerobic power and capacity. Aust. J. Sci. Med. Sport. 19: 13–17
21. Moore R. L., Stull J. T. (1984) Myosin light chain phosphorylation in fast and slow skeletal muscles in situ. Am. J. Physiol. 247: C462–C471
22. Pacheco B. A. (1957) Improvement in jumping performance due to preliminary exercise. Res. Q. Exerc. Sport. 28: 55–63
23. Proske V., Morgan D. L., Gregory J. E. (1993) Thixotropy in skeletal muscle spindles: a review. Progress in Neurobiology. 41: 705–721
24. Pyke F. S. (1968) The effect of preliminary activity on maximal motor performance. Res. Q. Exerc. Sport. 39: 1069–1076

25. Ranatunga K. W., Sharpe B., Turnbull B. (1987) Contractions of human skeletal muscle at different temperatures. J. Physiol. 390: 383–395
26. Sargeant A. J., Dolan P. (1987) Effect of prior exercise on maximal short-term power output in humans. J. Appl. Physiol. 63: 1475–1480
27. Spencer M., Lawrence S., Rechichi C., Bishop D., Dawson B., Goodman C. (2004) Time-motion analysis of elite field-hockey: special reference to repeated-sprint activity. J. Sports. Sci. In Press
28. Thompson H. (1958) Effect of warm-up upon physical performance in selected activities. Res. Q. Exerc. Sport. 29: 231–246
29. Ulmer H. V. (1996) Concept of an extracellular regulation of muscular metabolic rate during heavy exercise in humans by psychophysiological feedback. Experentia. 52: 416–420
30. Wright V., Johns R. J. (1961) Quantitative and qualitative analysis of joint stiffness in normal subjects and in patients with connective tissue disease. Ann. Rheum. Dis. 20: 36–46

Correspondence to:
David Bishop
Team Sport Research Group
School of Human Movement and Exercise Science
The University of Western Australia
Crawley, WA 6009
AUSTRALIA

UNIFICATION OF GERMANY IN REGARD TO SPORT, PHYSICAL EDUCATION, AND SPORT SCIENCE: AN ANALYSIS FROM A SOCIAL-CULTURAL PERSPECTIVE*

H. Haag
Institute of Sport and Sport Sciences,
University of Kiel, Kiel, Germany

Unification in Germany: Unexpected Chance of Worldwide Importance

The confrontation of the union with the government in Poland as well as the west-oriented politics in the Czech Republic and Hungary were the actual incentives for the opening of the iron curtain in 1989 [1]. The deeper reason for the end of the east-west division of the world was, however, the fact, that the communist countries could not keep up with the development in the highly industrialized countries of the Western world in regard to economics, technological advancement, information technology and standard of living.

The real difference of West and East thus was based on two different economic systems. Planned economy in the East (e.g. Russia) and free-lance capitalism in the West (e.g. USA). These two extremes are more or less easy to realize, but in the extreme form not acceptable from a humanistic point of view [7].

---

* This article is based on an invited speech for the 2004 ICPE conference in Hong Kong, July 7–11, 2004

While the GDR had the planned economy system the FRG tried after 1945 the so called "social market economy" system, a compromise between individual and social guidelines for shaping the economy. Experts in general consider this economic system as worthwhile to be installed worldwide, which is a huge task in the time of globalization. It is today more or less realized in the unified Germany.

The differences in the system of sport, physical education, and sport science are therefore based on the economic systems valid until 1989 in both German states. Thus the political unification in Germany opened a chance for unification in the three sport-specific dimensions.

These processes are analyzed in this paper, which is composed of three parts:

- Research Procedure
- Theoretical Framework
- Basic Concepts to Be Unified

In "Concluding Comments" the results of the analysis from a social-cultural perspective are presented in a summarized form.

1. Research Procedure

· Philosophy of Science	· Techniques of Data Collection
· Research Methods	· Techniques of Data Analysis
· Research Design	· Theory-Practice Relationship

The used research procedure is described along the "Kiel Model of Research Methodology" (KMRM) for sport science [6].

· Considerations in regard to "Philosophy of Science" confirm, that pursueing the given topic of unification in Germany related to sport, physical education, and sport science is a worthwhile and needed research topic. This relates to generate knowledge about this process, to help for its rational understanding, and to open perspectives for an optimal shaping of this process in the future, since the unification also in regard to sport-specific issues is not yet finished.

- The used "Research Method" is description with a historical and a comparative dimension. If these two dimensions are combined, a relatively complex form of the descriptive method has to be applied.
- Issues of "Research Design" relate especially to the data base, which consisted mainly of documents, observations and action-theory-based personal involvement in the process (e.g. member of commissions to change the former "Sektion Sportwissenschaft" into a "Institut für Sportwissenschaft" at the University of Rostock and Greifswald as well as transforming the world-wide known "Deutsche Hochschule für Körperkultur" into a "Sportwissenschaftliche Fakultät" of the University of Leipzig).
- The "Techniques of Data Collection" in consequence are related to content collecting and informal observation. The University of Potsdam opened after 1990 an "Institut für Zeitgeschichte des Sports" with the special task to do research on sport, physical education, and sport science in the former GDR [10].
- The "Techniques of Data Analysis" are hermeneutical strategies for data treatment and data analysis in order to derive scientifically based knowledge about the sport-related unification process.
- The "Theory-Practice Relationship" is given clearly, since the unification is a process with deep concern for all Germans it is not yet finished, and there are still chances to realize the objective "out of one + one make a better third" in an acceptable way.

2. Theoretical Framework

In order to understand the unification process in general as well as related to sport, physical education, and sport science it is necessary to explain a theoretical framework in the two dimensions "Unification Process" and "Philosophical Foundation".

2.1. Unification Process in Germany

First of all the following figure is representing Germany in 1945 after the end of World War II. This geographic notion is important as background knowledge.

Figure 1. Map of Germany in 1945

Furthermore the data in the following table transmit baseline knowledge about the two German states.

Table 1. Baseline data related to the two German states

GDR	FRG
Population: 17.042.000	Population: 69.200.000
Population density: 157 p/km²	Population density: 250p/km²
Size of Country: 108178 km²	Size of Country: 470662 km²
Government: since 1954 Ministerrat	Government: Bundestag/Bundesrat
Administration: central administration monopol	Administration: not central
Economics: centralistic planned economy	Economics: social market economy
Agriculture: since 1952 "production-cooperative societies" (LPG)	Agriculture: no cooperative societies
Foreign Trade: predominant to the East block states	Foreign Trade: predominant to the West block states
Military: "Nationale Volksarmee"	Military: "Bundeswehr"

The unification process has to be understood on the basics of these presented facts, in order to really understand the starting point of this unification process.

2.2. Philosophical Foundation: Two Different Positions

The philosophy of science also in regard to sport science can be distinguished in two lines of theories–epistemiology and scientific theory — which are presented in the following figure [5]:

Theories how to Gain Knowledge (examples)	Theories how to Perceive Science (examples)
- Empirism - Hermeneutics - Phenomenology	- Idealism - Dialectic Materialism - Critical Theory - Critical Rationalism - Logical Empirism - Positivism

Figure 2. Philosophy of science in regard to sport science

By taking two examples for "theories how to perceive science" the two different positions in regard to a philosophical foundation in the GDR and the FRG can be explained as a necessary theoretical framework for this analysis of the unification process.

East (GDR): Example: Dialectic Materialism (Dogmatism)
Characterized by four Basic Principles:
Rationality: Explain the World by Itself
Objectivity: Sensations of Man are Patterns of the Objective and Real Outside-World
Uniformity: Nature, Society, and Thinking are Explained from one Cause: Moving Material
Practice: Human Practice as Foundation and Purpose of Theory

West (FRG): Example: Critical Theory (Frankfurt School) (Pluralism)
Combination of Rationality (Relative), Human Rights, Justice, Democracy
Aesthetic-Expressive and Moral-Practical Aspects
Originating of Science and Transfer of Scientific Results (Kiel-Model of Research Methodology)
Empirical and Hermeneutical Approaches to Knowledge Generating

Both scientific theories are well established and of high interest. The major difference, however, was, that in the GDR the "Dialectic Materialism" was taken as dogmatism, the only admitted scientific theory.

In the FRG the "critical Theory" was accepted as one theory of science within many; this is called a pluralistic view.

3. Basic Concepts to Be Unified

The dimension of concepts is analyzed in the following by using three different concepts as "tertium comparationis" for a comparison between the GDR and the FRG: Sport, physical education, and sport science.

3.1. Concept of Sport: Two Different Sport Systems

The East was characterized by a monolithic one column system (run by the state); the West was characterized by a dual column system with the two parts "public sport administration" and "self administration of sport". Both systems are presented in the following Figure 3.

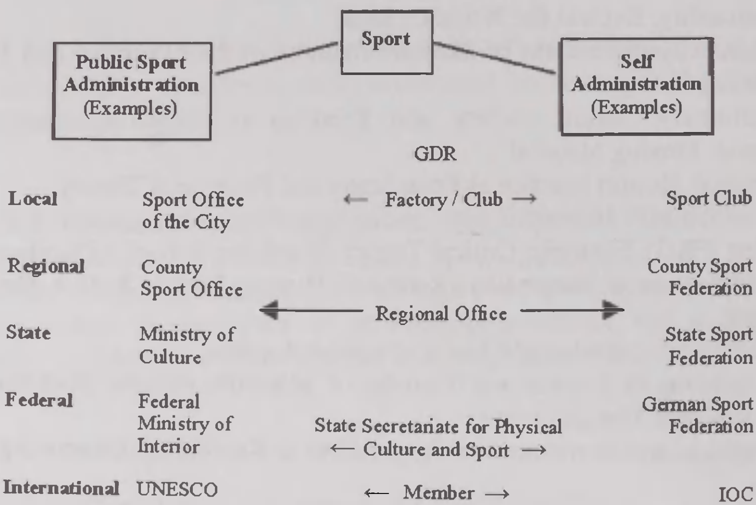

Figure 3. Monolithic and dual sport systems

The dual system is accepted today worldwide. There can even a tendency be observed that a three-column system will be developing in the future with a third column, called economic system of sport (compare the tendency for commercialization in the world of sport).
In the unified Germany today it can be observed that the total sub-system of the society, called “sport”, can be observed in five different areas, as described in the following Figure 4:

Sport Areas				
Professional Sport	Sport in State Institutions	Club Sport	Sport in Commercial Offerings	Private Sport

Figure 4. Five sport areas

These five areas of sport are administrated, so to speak, already today by the projected three column system.

3.2. Concept of Physical Education: Bipolar Approach (Socialistic-Collectivistic and Individual-social)

The anthropological guideline of the East and the GDR was the so called “socialistic personality” as formulated already by the philosopher Karl Marx. Major elements of this socialistic personality are the following as background for physical education in the GDR:

East (GDR) (Marx Foundation)
Major elements of human behavior (socialistic personality)

- activity (productive power)
- fighting
- dynamic acting
- willingness
- motor behavior in work
- love for the nation
- collective behavior
- internationality

In consequence the curriculum for physical education in the GDR contained the following aims and objectives [9]:

Aims and Objectives of Physical Education:

- Deepening of sportive interests
- Education for loving work
- Education for loving the own country (including military education)
- Strengthening the school collective
- Combination of individual and collective interests
- Education for self-activity
- Education for order and discipline
- Development of socialistic character traits
- Education for proletaric internationalism

Thus it becomes relatively clear, how the concept of physical education in schools looked like on the basis of a socialistic-collectivistic anthropology.

Looking at the West and the FRG the anthropological guideline is explained in the following by presenting three examples of theories, which represent the individual-social balance as framework for the development of the personality also through physical education (Figures 5–7).

Anthropological Foundations

The Concept of Human Movement

experiences → in surrounding	through → movement	**person** →	through → movement	communication with surrounding

Figure 5. Anthropological Foundation [2].

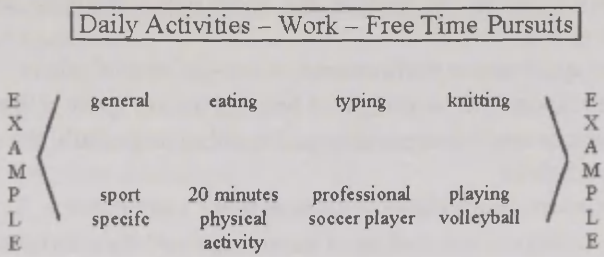

Figure 6. Theory of emancipation through movement [3]

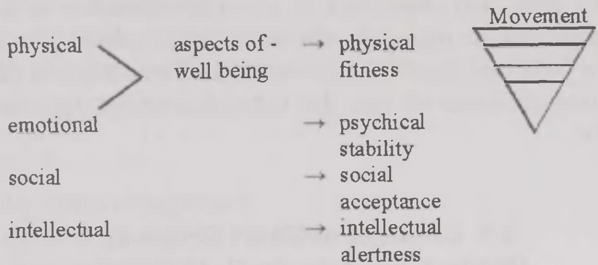

Figure 7. Human well-being and movement [4]

Considering these three anthropologically oriented theories the following aims and objectives of physical education in schools can be better understood (the example is taken from the state of Schleswig-Holstein, 1978, pp. 4–7)

Aims of School P.E. [8]
- Meet movement needs and joy for play
- Experience and improve rhythmical activities
- Develop sport-motor-skills
- Recognize the dependability of motor performance from basic motor abilities
- Acquire movement forms for daily life and work activities

- Get knowledge to be applied for sport-motor-learning and independent acting
- Evaluate sport-motor performance of oneself and of others
- Practice responsible securing and helping during sport action
- Initiate processes for exercising and training, especially for sport for all in sport clubs
- Recognize the relationship of sport activity and health
- Helping in organization of sport instruction and sport events
- Understand and evaluate aspects of the social sub-system called sport in a differentiated way

By help of looking at the anthropological patterns and by naming examples for aims and objectives of physical education in school the bipolar approaches in regard to the concept of school physical education in the GDR and the FRG become clear. The pattern in the unified Germany today is more or less the individual-social approach of the former FRG.

3.3. Concept of Sport Science: Positive Aspects on Both Sides

The comparison of sport science in the GDR and the FRG will be facilitated by informing on the following three aspects:
(a) Administration and Management of Sport Science, (b) Strong Aspects in Sport Science, and (c) Access to Literature.

(a) Administration and Management of Sport Science
(b)
East (GDR)
Four state institutions with strong relations to sport science: Staatssekretariat für Körperkultur und Sport (Berlin-Ost), Deutsche Hochschule für Körperkultur (DHfK) (Leipzig), Forschungs- und Entwicklungsstelle für Sportgeräte (FES) (Berlin-Ost), Forschungsinstitut für Körperkultur und Sport (FKS) (Leipzig) (today IAT) (for the last two see addresses).

All responsibility centralized with the "Staatssekretariat für Körperkultur und Sport"

West (FRG)
Four federal institutions with strong relations to sport science (BISp, DOJ, FA, TA) (see addresses)
Sport for all, school sport, sport science = state responsibility
top level athletics (including scientific aspects and facilities) = federal responsibility

(b) Strong Aspects in Sport Science
East (GDR)
Empirical research approach
Research in regard to sport disciplines
Consequent transfer of science to practice
Planned research concentrations

West (FRG)
Hermeneutic research approach
Research on more general sport related concepts
Pluralistic view of scientific theories
"Free market" in research concentrations

(c) Access to Literature
East (GDR)
Library of the Faculty of Sport Science of the University of Leipzig (former DHfK)
Library of the new sport science institutes in the "Neue Bundesländer":
Berlin , Chemnitz, Dresden, Erfurt,
Greifswald, Halle, Jena, Magdeburg, Potsdam, Rostock

West (FRG)
Library of the BISp
Library of the "Deutsche Sporthochschule Köln"
Spolit–Databank System (BISp)

The area (a) "Administration and Management of Sport Science" was organized quite different in both states. Three institutions of the GDR continue to exist in the unified Germany however in a different make-up (DHFK → "Sportwissenschaftliche Fakultät" of the University of Leipzig; FES → FES in Berlin; FKS → "Institut für Angewandte Trainingswissenschaft" IAT.) Besides this the approach of the West-FRG is valid for the unified Germany.

The area (b) "Strong Aspects in Sport Science" should be added from both sides. This would result in eight points making up a very strong concept for sport science. This also would be an excellent example for the perspective and vision "out of one + one make a better third". This is reality today more or less in the unified Germany.

The area (c) "Access to Literature" fortunately enough has been solved in a very pragmatic way, since all the mentioned places, where one can access literature are still available. The advancement of information technology has supported the information retrieved in the meantime to a great extent. Both German states had in the past already a very advanced development of information and documentation in regard to sport science, which was helpful to have today in the unified Germany a relatively high standard in this regard.

Concluding Comments (Results of the Analysis from a Social-Cultural Perspective)

The results of this analysis can be summarized in the following four points:

(a) Whenever one is doing cross-cultural research a "tertium comparationis" is needed. The three constructs–sport, physical education, sport science–can be distinguished quite well in this regard. From a historical point of view this sequence is logical: First there was and is sport as the sum of actions human beings are realizing by actualizing their body in movement. Then educational considerations come into the picture, thus developing physical education. Finally in the last century sport science developed gradually and is today a recognized and well established academic discipline. The three constructs therefore represent the field in a holistic way, so that the comparison in regard to two different systems and countries is valid.

(b) The theoretical frameworks and background ideologies were quite different in both states. Consequently the systems of sport, physical education, and sport science had to be unified starting almost from two bipolar positions. The inherent character of sport, namely to perform, to compete, to excel, and to be number one nevertheless was the same in both countries.

(c) In both systems of sport, physical education, and sport science positive and negative characteristics were inherent. Therefore Germany has, starting since 1989, the unique chance to make out of "one + one a better third". 15 years after the beginning of the unification process two points can be stated: The unification process is not yet finished and the chance to develop a better "third" has not yet been realized to a satisfactory extent. There is hope to still use this chance creatively.

In summary, the years 1989 till today offered a unique and seldom given opportunity to merge two very different systems related to sport, physical education, and sport science in a peaceful way. This process, however, is not yet finished, and it is hoped that the world can learn from the experiences made in the unification process in Germany.

References

1. Bahrmann H., Links C. (1999) The fall of the wall. The path to German reunification. Berlin: Chr. Links Verlag
2. Gruppe O. (1982) Bewegung, Spiel und Leistung im Sport. Grundthemen der Sportanthropologie. Schorndorf: Hofmann
3. Haag H. (1986) Bewegungskultur und Freizeit. Vom Grundbedürfnis nach Sport und Spiel. Zürich: From
4. Haag H. (1989) Sportpädagogik. In H. Haag H., Strauß B. G., Heinze S. (Red.). Theorie- und Themenfelder der Sportwissenschaft (S. 48–69). Schorndorf: Hofmann

5. Haag H. (Hrsg.) (1996) Sportphilosophie. Ein Handbuch. Schorndorf: Hofmann
6. Haag H. (Ed.) (2004) Research methodology for sport and exercise science. A comprehensive introduction for study and research. Schorndorf: Hofmann
7. Haag H. (2004) Is there actual value to sport in capitalistic societies? ICSSPE-Bulletin 40: 41–44
8. KM Schleswig-Holstein (Hrsg.) (1978) Lehrplan Realschule Sport. Kiel: IPTS
9. Kramer H. J. (1969) Körpererziehung und Sportunterricht in der DDR. Schorndorf: Hofmann
10. Krüger M. (1993) Einführung in die Geschichte der Leibeserziehung und des Sports. Teil 3: Leibesübungen im 20. Jahrhundert (Sport für alle). Schorndorf: Hofmann

Correspondence to:
Herbert Haag
Institute of Sport and Sport Sciences
University of Kiel
Kiel
Germany

Acta Kinesiologiae Universitatis Tartuensis, 2004, Vol. 9

PERFORMANCE MARKERS AND SIDEDNESS IN FEMALE ELITE TAEKWONDO ATHLETES: A PILOT STUDY

W. Pieter[1], G. D. Kim[2]
[1] *Exercise Research Associates, Ann Arbor, MI, USA*
[2] *Department of Sport and Leisure Studies, Semyung University, Jucheon, Choongbok, Korea*

ABSTRACT

The purpose of the current investigation was to assess performance time, velocity and momentum when executing the roundhouse kick in adult elite female *taekwondo-in* (taekwondo athletes). Subjects ($n = 5$) were members of the American national team, who participated in a training camp at the United States Olympic Training Center in Colorado Springs, CO. Performance time after a visual signal, velocity measured with an electronic dual-beam timing light system, and bag impact momentum were assessed. Performance time for the left leg at T2 (0.65 ± 0.07s) was shorter than for the right leg at T1 (0.75 ± 0.07s, $p = 0.005$). Performance time for the left leg at T3 (0.66 ± 0.07s) was also shorter than for the right leg at T1 ($p = 0.006$). There were no differences in velocity between legs, over time or their interaction. Momentum for the left leg (11.81 ± 0.62 kg.m/s) was lower than that for the right (13.38 ± 1.27 kg.m/s) ($p = 0.02$). The female *taekwondo-in* in the present study should consider working on their left side to minimize the difference in momentum with the right leg.

Key words: performance, taekwondo, females

INTRODUCTION

Performance in taekwondo depends on many factors. Some of them belong to the domains of sport physiology [2], sport biomechanics [11] and sport psychology [1]. Other measures of performance not often investigated in martial arts in general and taekwondo in particular include reaction and movement time. For instance, Layton [3] reported the reaction plus movement time (i.e., performance or response time) of the left and right front kick in karate to be 0.723 sec and 0.720 sec, respectively.

Velocity and speed in taekwondo and karate were also investigated. In one of the oldest studies on karate, Vos and Binkhorst [14] reported velocities of 12–14 m/s for the downward knife hand strike (*shuto uchi*), while Wilk et al. [15] found 5.7–9.8 m/s for the front forward punch (*seikan zuki*) and 9.5–11 m/s for the roundhouse kick. Serina and Lieu [9] reported average foot velocities of 15.9 m/s for swing kicks, such as the roundhouse kick, while Pieter and Pieter [8] found speeds for the roundhouse kick of 15.51–16.26 m/s and 12.84–13.79 m/s for adult elite male and female *taekwondo-in* (taekwondo athletes), respectively.

Bag momentum for high skilled male *karateka* (karate athletes) was higher (60.79 N.s) than those of intermediate (39.98 N.s) or low (42.34 N.s) skilled counterparts when executing the reverse punch [10]. Pieter and Pieter [8] reported force values for adult elite male *taekwondo-in* for the roundhouse kick of 518.7 N (right leg) and 510.5 N (left leg) upon impact with the bag. The women recorded 406.6 N and 404.1 N for the right and left leg, respectively. Sung et al. [12] found a performance time (i.e., reaction time + movement time) for the roundhouse kick upon impact of 0.645 sec in elite male Korean *taekwondo-in*. Luk and Hong [5] reported the movement response time of the roundhouse kick off the front leg (0.71 sec) to be faster than off the back leg (0.80 sec). Movement response time was calculated as the time elapsed between the synchronized signal after a light-emitting diode was triggered until the kicking foot impacted the bag.

The purpose of the current investigation was to assess performance time, velocity and momentum when executing the roundhouse kick in adult elite female *taekwondo-in*. The study was part of the Oregon

Taekwondo Research Project (OTRP) that was initiated during the first author's tenure at the University of Oregon, USA.

METHODS

Subjects were 5 adult female elite taekwondo athletes (26.40 ± 5.99 years; 165.80 ± 6.58 cm; 54.56 ± 8.42 kg), who were members of the American national team and who participated in a training camp at the United States Olympic Training Center in Colorado Springs, CO. Height was measured with a stadiometer to the nearest 0.5 cm, and body mass was assessed with a calibrated digital scale to the nearest 0.5 kg.

After an appropriate warm-up, subjects performed the roundhouse kick at their mid-section height (the bag could be adjusted to the subject's target height) with both the right and left leg and were allowed five trials with each limb. Average velocity during the last 1 cm before impact with the bag ("impact velocity") was measured with an electronic dual-beam timing light system interfaced with a Campac Portable III computer. Performance time, which was the latency time when the signal light first came on and the athlete's kicking foot left the pressure platform until the leg passed the first photocell beam, was recorded in seconds. Momentum (in kg.m/s) was measured with a water-filled heavy bag (Impax™ Powair, Impulse Sports Training Systems, Inc., Bay Village, OH, USA) with a built-in force sensor unit and interfaced with a Data General Dasher/286 (Sportsoft Impulse) computer.

The data were analyzed for skewness and kurtosis, while the Kolmogorov-Smirnov test was used to assess normality. The L statistic [13] was used in cases where the distributions were not normal. The differences in performance time, velocity and momentum between legs across the five trials, i.e., over time, were analyzed by means of a 2-way (Leg × Time) ANOVA with repeated measures on the second factor. To determine equality of error variance, the Levene's test was used. Simple effects analysis was employed after a significant 2-way interaction. A Tukey HSD post-hoc test was utilized to locate the exact differences when a Time main effect was found. The level of significance was set at 0.05.

RESULTS

Tables 1–3 show the means and standard deviations of performance time, velocity and momentum, respectively, by leg across trials. The performance time data were normally distributed. The Levene's test of equality of error variance was not significant. There was a Leg × Time interaction for performance time ($p = 0.039$, $eta^2 = 0.264$). Simple effects analysis revealed that performance time for the left leg at T2 was shorter than for the right leg at T1 ($p = 0.005$). Performance time for the left leg at T3 was also shorter than for the right leg at T1 ($p = 0.006$), as was performance time for the right leg at T5 ($p = 0.003$). Finally, there was a Time main effect for performance time ($p = 0.022$, $eta^2 = 0.294$). The Leg main effect for performance time was not significant ($p > 0.05$, $eta^2 = 0.073$).

Table 1. Descriptive statistics for performance time (in seconds) by leg across trials

Trial time (T)	Left leg	Right leg
T1	0.68 ± 0.07	0.75 ± 0.07
T2	0.65 ± 0.06	0.68 ± 0.06
T3	0.66 ± 0.07	0.71 ± 0.06
T4	0.68 ± 0.05	0.71 ± 0.13
T5	0.68 ± 0.06	0.65 ± 0.04

Table 2. Descriptive statistics for velocity (in m/s) by leg across trials

Trial time (T)	Left leg	Right leg
T1	11.08 ± 1.71	11.16 ± 2.09
T2	10.61 ± 1.25	11.48 ± 2.03
T3	10.47 ± 1.72	11.40 ± 2.31
T4	10.61 ± 1.22	11.52 ± 2.60
T5	10.56 ± 1.25	11.41 ± 2.44

Table 3. Descriptive statistics for momentum (in kg.m/s) by leg across trials

Trial time (T)	Left leg	Right leg
T1	11.88 ± 0.83	13.34 ± 0.50
T2	11.58 ± 0.71	12.85 ± 1.02
T3	11.94 ± 0.66	13.28 ± 2.34
T4	11.64 ± 0.76	13.58 ± 1.55
T5	12.00 ± 1.72	13.82 ± 1.94

Velocity for some of the trials was not normally distributed, so the L statistic was employed to analyze the data. The Levene's test of equality of error variance was not significant. Since the sphericity assumption was not met, the Greenhouse-Geisser correction was used. No interaction for velocity was found ($p > 0.05$, $eta^2 = 0.102$). There also was no Time ($p > 0.05$, $eta^2 < 0.001$) or Leg main effect ($p > 0.05$, $eta^2 = 0.091$).

The L statistic was employed to analyze the data on momentum, because some of the trials were not normally distributed. The Levene's test of equality of error variance for momentum was not significant. There was no Leg × Time interaction for momentum ($p > 0.05$, $eta^2 = 0.053$). There also was no Time effect ($p > 0.05$, $eta^2 < 0.001$). However, there was a Leg main effect ($p = 0.02$, $eta^2 = 0.600$) with the right leg recording a higher momentum: 13.38 ± 1.27 kg m/s versus 11.81 ± 0.62 kg m/s.

DISCUSSION

No studies on performance time in female martial arts athletes in general and *taekwondo-in* in particular could be located. Layton [3], using an auditory signal, found that performance time in karate did not differ between left and right sides. The author reported the performance time for the roundhouse kick in male *karateka* to be 0.763 seconds and 0.753 seconds for the left and right side, respectively. Elite Korean male *taekwondo-in* recorded a performance time of 0.645 seconds for the right roundhouse kick in response to a visual stimulus [12]. Elite

Korean male *taekwondo-in* competing in a dual meet against The Netherlands recorded a performance time of 0.440 seconds for the same kick during their matches [6]. Members of the Austrian men's national taekwondo team recorded performance times of 0.63 seconds and 0.62 seconds for the left and right leg, respectively, while executing the roundhouse kick in response to a visual signal [4]. More research on female martial arts athletes is clearly indicated.

Velocity of the roundhouse kick in the female *taekwondo-in* was comparable to that recorded in male *karateka* (9.5–11 m/s) [15]. It was much slower than that reported for male elite Korean *taekwondo-in* (22.90 m/s) [12]. Elite Korean male *taekwondo-in* competing in a dual meet against The Netherlands recorded an "impact" velocity of 13 m/s during actual bouts instead of in the laboratory [6]. The velocity of the roundhouse kick in male recreational New Zealand *taekwondo-in* was 13.4 m/s [7]. The only other study for which female elite *taekwondo-in* were investigated reported roundhouse kick speeds of 12.84 m/s and 13.79 m/s for the left and right legs, respectively [8]. The authors did not find any statistically significant difference in between the left and right side, which was confirmed by the current study with trivial effect sizes. The small effect size of the performance time seems to suggest a slight sidedness in the execution of the roundhouse kick in the female *taekwondo-in* investigated, with the left leg recording a shorter performance time in the beginning.

Momentum for the elite Korean *taekwondo-in* tested in the laboratory was 10.99 kg.m/s [12], which was lower than that of their American female counterparts in the current study. One possible explanation may be that the Korean athletes used a hand-held target, while the subjects in the current study kicked against a heavy bag. The Koreans also had a problem hitting the target accurately [12], which was not the case for the American females, who had a larger area to hit with the heavy bag.

It stands to reason to assume that *taekwondo-in* have to be able to maintain optimal performance time, velocity and momentum throughout a tournament. It is also reasonable to suggest that athletes would want to be able to kick with either leg, since competitive situations constantly change: sometimes it is more productive to kick with the left and at other times, with the right. The results of the present study seem to indicate that there is a small difference between legs in performance time, with a moderate one in momentum. As was suggested before [8], the female *taekwondo-in* in the present study should consider working on their left side to minimize the difference in momentum with the right leg.

ACKNOWLEDGEMENTS

The study was funded by the United States Olympic Committee and in kind by the United States Taekwondo Union. The authors are grateful to Sarah Smith, Ph.D. and her research assistants at the time of the investigation for their help with data collection as well as to the athletes who volunteered to participate in the project. Appreciation is also extended to the coaching staff.

REFERENCES

1. Chung S., Orlick T., Pieter W. (1997) Mental skills of elite Canadian taekwondo athletes. In: ICHPER.SD 40th World Congress Proceedings. Seoul, Korea: Kyunghee Univ. 67–69
2. Heller J., Perič T., Dlouhá R., Kohlíková E., Melichna J., Nováková H. (1998) Physiological profiles of male and female taekwondo (ITF) black belts. J. Sports Sci. 16: 243–249
3. Layton C. (1993) Reaction + movement time and sidedness in shotokan karate students. Percept. Mot. Skills. 76: 765–766
4. Lehmann G., Mosch N., Lilge W. (1993) Untersuchungen zur Struktur der Leistungsvoraussetzungen des Taekwondokämpfers. Leistungssp. 24: 21–26
5. Luk T. C., Hong Y. (2000) Comparison of electromyography activity between different types of taekwondo round-house kick (sic). In: Proceedings of XVIII International Symposium on Biomechanics in Sports, Hong Y., Johns D. P. (eds). Hong Kong: Department of Sports Science and Physical Education, Chinese University of Hong Kong, 920–924

6. Müskens M., Veeger H. E. J. (no date) Biomechanische Analyses bij Taekwondo Technieken Tijdens Wedstrijdsituaties. Amsterdam: Vrije Universiteit.
7. Pearson J. (1997) Kinematics and kinetics of the taekwon-do turning kick. Unpublished undergraduate thesis, University of Otago, Dunedin, New Zealand
8. Pieter F., Pieter W. (1995) Speed and force of selected taekwondo techniques. Biol. Sport. 12: 257–266
9. Serina E. R., Lieu D. K. (1991) Thoracic injury potential of basic competition taekwondo kicks. J. Biom. 24: 951–960
10. Smith P. K., Hamill J. (1986) The effect of punching glove type and skill level on force transfer. J. Hum. Mov. Stud. 12: 153–161
11. Sørenson H., Zacho M., Simonsen E. B., Dyhre-Poulsen P., Klausen K. (1996) Dynamics of the martial arts high front kick. J. Sports Sci. 14: 483–495
12. Sung N. J., Lee S. G., Park H. J., Joo S. K. (1987) An analysis of the dynamics of the basic taekwondo kick. US Taekwondo J. VI 2: 10–15
13. Thomas J. R., Nelson J. K., Thomas K. T. (1999) A generalized rank-order method for nonparametric analysis of data from exercise science: a tutorial. Res. Quart. 70: 11–23
14. Vos J. A., Binkhorst R. A. (1966) Velocity and force of some karate movements. Nature. 211: 89–90
15. Wilk S. R., McNair R. E., Feld M. S. (1983) The physics of karate. Am. J. Phys. 51: 783–790

Correspondence to:
Willy Pieter
School of Health Sciences
Science University of Malaysia
Kubang Kerian
Kelantan 16150
Malaysia

Acta Kinesiologiae Universitatis Tartuensis, 2004, Vol. 9

POSTACTIVATION POTENTIATION IN HUMAN KNEE EXTENSOR MUSCLES AFTER TWO DIFFERENT CONDITIONING ACTIVATIONS

B. Requena[1,2], I. García[2], J. Ereline[1], H. Gapeyeva[1], M. Pääsuke[1]

[1] *Institute of Exercise Biology and Physiotherapy, University of Tartu, Tartu, Estonia*

[2] *Department of Physical Education and Sport, University of Granada, Granada, Spain*

ABSTRACT

This study compared postactivation potentiation (PAP) in the knee extensor (KE) muscles after a brief (7-s) isometric maximal voluntary contraction (MVC trial) and submaximal percutaneous electrical stimulation at 100 Hz (PES trial) as conditioning activations. Thirteen young (aged 19–27 years) healthy men participated in this study. The subjects sat on the dynamometric chair. To assess the tetanic contractile properties of KE muscles, a supramaximal PES of the femoral nerve was used by recangular pulses of 1-ms duration at 10 Hz during 1 s, whereas peak force (PF) of the unfused tetanic contraction was measured. In MVC trial, a significant PAP was observed during 3 min after a conditioning activation. Potentiation of tetanic contraction PF was greater immediately after a conditioning activation with sharp and linear decay at 1 and 3 min after activation. In PES trial, a significant PAP was observed immediately, 1, 3 and 5 min after a conditioning activation, whereas potentiation of tetanic contraction PF was greater at 1 min after activation. In conclusion, this study indicated a significantly higher PAP in KE muscles immediately after a conditioning MVC compared with submaximal direct PES interspersed with similar moderate level PAP at 3 min after conditioning activations.

Key words: postactivation potentiation, knee extensor muscles, percutaneous electrical stimulation, maximal voluntary contraction

INTRODUCTION

The contractile response of a muscle depends to a great extent on the history of its activation. A brief repetitive percutaneous electrical stimulation (PES) may result in enhanced contractile response (potentiation) while continued stimulation results in impaired or attenuated contractile response (fatigue) [19]. Potentiation may be defined as staircase, observed during low-frequency stimulation, and postactivation potentiation (PAP), observed after a high-frequency tetanic stimulation or maximal voluntary contraction (MVC) [11, 22, 26]. PAP is greatest immediately after the conditioning contraction induced by MVC or supramaximal PES and then decays rapidly but is still evident for ~5 min [9, 14].

PAP is often associated with increased peak force, maximal rates of force development and relaxation of supramaximal isometric twitch and a shortening of twitch contraction (CT) and half-relaxation (HRT) times [7, 14, 16, 18]. Moreover, muscles with the shortest twitch CT and HRT and highest proportion of fast-twitch fibers show the greatest PAP [9]. The most accepted mechanism of PAP is phosphorylation of myosin regulatory light chains during a conditioning activation, which renders actin-myosin more sensitive to Ca^{2+} in subsequent contraction [6, 15]. Several studies have evaluated the effect of PAP on isometric twitch peak force [3, 13]. However, little is known about the effect of PAP on low-frequency (unfused) tetanic contraction characteristics. In this sense, recruitment of motor units (MUs) during voluntary contractions occurs with frequencies of stimulation which result in unfused tetanic contractions of the skeletal muscles [2, 21].

The magnitude of PAP is influenced by the methods and conditions under which it is evoked. Potentiation is affected by the intensity, frequency, and duration of the conditioning tetanic stimulation [6]. The supramaximal PES at high frequency for ~5–10 s causes the greatest immediate PAP [7]. However, supramaximal tetanic nerve (indirect) or muscle (direct) electrical stimulation could potentially induces muscle injury, pain, or discomfort [4]. Submaximal direct PES is often used for prevention and/or restoration of muscle function after injuries, and as a modality of strengthening in healthy subjects and elite athletes [8]. The recruitment pattern of MUs during PES is different from that reported during voluntary contractions. It appears that during PES fast-twitch muscle fibers with greater force-generation and force-potentiation capacity can be activated at relatively low stimulation intensities [5]. However, the differences in potentiation magnitude in human skeletal muscles induced by two often used conditioning activations — MVC and submaximal high-frequency direct PES are not well investigated.

The aim of the present study was to evaluate the effect of PAP induced by a conditioning brief (7-s) isometric MVC and high-frequency submaximal PES. We measured changes in 10-Hz isometric tetanic contraction peak force (PF) immediately and 10 min after a conditioning MVC and tetanic contraction at target force level of ~25%MVC of KE muscles.

MATERIAL AND METHODS

Subjects

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

Apparatus and Experimental Procedure

During the measurement, the subject sat on the custom-made dynamometer with the knee and hip angles equal to 90° and 110°, respectively [17]. The body position of the subject was secured by Velcro belts placed over the chest, hip and thigh. The unilateral knee extension isometric force of the dominant leg was recorded by standard strain-gauge transducer mounted inside a metal frame which was placed around the distal part of the ankle above the malleoli using a Velcro belt. The electrical signals from the strain-gauge transducer were digitized on-line (sampling frequency 1kHz) using a personal computer. The digitized signals were stored on a hard disk for further analysis.

To assess the contractile properties of the KE muscles of the dominant leg, electrically evoked 10 Hz-tetanic contractions were elicited by percutaneous nerve stimulation. Prior to attaching the stimulating electrodes, electrode gel was applied to the contact surface, and the underlying skin was prepared by shaving, sanding and rubbing with isopropyl alcohol. Two self-adhesive electrodes (Compex, Medicompex SA, Ecublens, Switzerland) were used — the cathode (5 × 5 cm) placed on the skin over the femoral nerve in the inguinal crease and the anode (5 × 10 cm) placed over the mid-portion of the thigh. The rectangular voltage pulses of 1-ms duration were applied at supramaximal intensity (130–150 V) from an isolated voltage stimulator (Medicor MG-440, Hungary). To determine the supramaximal stimulation intensity, the voltage of rectangular electrical pulse was progressively increased to obtain a plateau in the twitch force, i.e. when twitch force failed to increase despite additional increases in stimulation intensity. The same supramaximal stimulation intensity (~20% greater than that needed for maximal twitch response) was further used for 10-Hz tetanic contractions with the duration of 1 s, evoked before the conditioning activations and during the recovery period. Peak force (PF) of 10-Hz tetanic contraction as the highest value of isometric force production was calculated.

To induce potentiation in KE muscles by submaximal high-frequency PES, a portable battery-powered stimulator (Compex, Medicompex SA, Ecublens, Switzerland) was used. Three self-adhesive electrodes were placed over the thigh. The positive electrodes

(5 cm × 5 cm) were placed to the motor point area of vastus lateralis and vastus medialis muscle and near the proximal insertion of each muscle. The negative electrode (5 cm × 10 cm) was placed over the proximal-portion of the thigh between stimulating electrodes for tetanic contraction measurements. Rectangular voltage pulses of 0.4-ms duration at the frequency of 100 Hz were used. The stimulation voltage was calculated for each subject prior to the testing, according to individual force response.

Potentiation in KE muscles was assessed on two separate trials, during the 1st trial the muscles were potentiated by 7-s MVC (MVC trial) and during the 2nd trial by 7-s submaximal tetanic contraction (~25%MVC) induced by direct PES at 100 Hz (PES trial). Interval between the two trials was at least 48 h but not more than 4 days.

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

On reporting to the laboratory, the subject sat resting for ~ 30 min before the experiment for minimizing any potentiation effect from walking to the laboratory. In both trials, resting 10-Hz tetanic contraction PF (baseline values) was measured first. Three supramaximal 10-Hz tetanic contractions were evoked with 2 min rest interval and the attempt with greater PF was further analysed. Three min after the baseline testing of 10-Hz tetanic contraction PF had been established, MVC force of KE muscles was measured. The subject was asked to exert maximum voluntary isometric knee extension against the belt of the strain-gauge transducer as forcefully as possible during approximately 3 s. Three maximal attempts were recorded and the best result was taken for further analysis. A rest period of 2 min was allowed between the attempts.

During MVC trial, 15 min after the measurement of resting 10-Hz tetanic contraction PF (baseline value) and MVC force of KE muscles, a conditioning 7-s MVC was applied. During PES trial, 5 min after the measurement of baseline value of isometric 10-Hz tetanic contraction PF and MVC force of KE muscles, tetanic stimulation voltage for a target level of isometric force at 25% MVC was determinated and controlled by two separated 2-s stimulations with 1-min rest between stimulations. After 15 min resting, a conditioning 7-s tetanic contraction (~ 25% MVC) was evoked by direct PES at 100 Hz.

After the conditioning activation in MVC or PES trial, the subject sat relaxed on the apparatus during a 10-min recovery period. The testing of 10-Hz tetanic contractions of 1 s duration was performed immediately (after 5 s), and 1, 3, 5 and 10 min after conditioning activation.

Statistics

Data are means and standard errors of the mean (±SEM). Two-way analysis of variance (ANOVA) followed by Scheffe post hoc comparisons were used to test the differences between pre- and post-conditioning values and between MVC and PES trials. A level of $p<0.05$ was selected to indicate statistical significance.

RESULTS

Preconditioning tetanic contraction peak force. The mean preconditioning values of 10-Hz tetanic contraction PF were 98.8±32.9 and 96.9±6.9 N for MVC and PES trials, respectively. No significant differences were observed between two trials.

Changes in isometric force during conditioning contractions. Isometric force of KE muscles decreased significantly ($p<0.05$) during conditioning MVC and submaximal tetanic contraction induced by PES (10.9±2.1% and 20.2±2.2%, respectively). A greater ($p<0.05$) relative decrease in isometric force was observed in PES trial compared with MVC trial.

Postconditioning tetanic contraction peak force. Figure 1 indicates a time-course of changes in 10-Hz tetanic contraction PF during 10-min recovery period after conditioning activations. In MVC trial, a significant ($p<0.05$) PAP was observed during 3 min after conditioning activations. Potentiation of supramaximal 10-Hz tetanic contraction PF was greater immediately after 7s MVC contraction (43.4% from the initial value) with sharp and linear decay at 1 and 3 min after conditioning activation. No significant PAP was observed at 5 and 10 min after a conditioning activation. In PES trial, a significant ($p<0.05$) PAP was observed immediately, 1, 3- and 5 min after a conditioning activation. Potentiation of 10-Hz tetanic contraction PF was greater 1 min after conditioning activation (19.6% from initial value) and then decreased slightly but remained significant at 5 min recovery period (14.5% from the initial value). No significant PAP was observed at 10 min after conditioning activation. A significantly higher ($p<0.05$) potentiation of 10-Hz tetanic contraction PF was observed immediately after conditioning MVC compared with PES, while no significant differences in potentiation between these trials were found 3, 5 and 10 min after a conditioning activation.

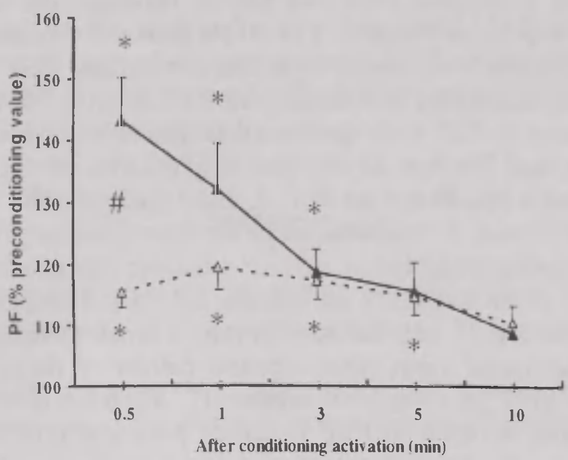

Figure 1. Changes in 10-Hz tetanic contraction peak force (PF) after a conditioning 7-s isometric maximal voluntary contraction (MVC, the solid line) and submaximal high-frequency percutaneous electrical stimulation (PES, the dashed line). Values, expressed as percentage of preconditioning value, are means ± SEM for 13 subjects. * Significantly different ($p<0.05$) from preconditioning value; # significantly different between MVC and PES trials.

DISCUSSION

The present study indicated that time-course of PAP was different for two 7-s conditioning activations proposed (MVC and submaximal direct PES) during the first part of recovery (immediately and 1 min after a conditioning contraction) with similar time-course of PAP during the later recovery period (3, 5 and 10 min after conditioning contraction). In agreement with previous studies [12, 24], the current study showed a transitory increase in 10-Hz tetanic contraction PF during the posttetanic period (first 3 min) after both conditioning activations proposed. PAP has been attributed to the phosphorylation of the regulatory light chains of myosin (RLC) by myosin light chain kinase, which alters cross-bridge interactions between thick and thin filaments [27], increasing the proportion of myosin heads in the force generating state at submaximal levels of Ca^{2+} activation [23].

In the present study, we hypothesized a similar PAP after both conditioning activations (PES and MVC). However, the results supported the hypothesis partially. The 10-Hz tetanic contraction PF after MVC was significantly higher than after submaximal PES at the first measurement during the posttetanic period (5 s). After 7-s submaximal PES the decay in PAP from the immediate posttetanic value was not a simple exponent function, as occurred in MVC-trial. During PES-trial, PAP showed a small increase at 1, 3, and 5 min followed by a small decrease at 10 min. A similar behavior has been previously observed in isometric supramaximal twitch after a 7-s indirect supramaximal tetanic stimulation at the frequency of 100 Hz [14, 20]. Twitch peak force declined over the 1st min but then showed a small increase at 2 min before it decreased again. This triphasic pattern of decay has been shown after MVC by several investigators [7, 26]. It has been suggested that the initial decrease in PAP is caused particularly by fatigue; as fatigue wanes, the level of potentiation increases again before falling away [26]. Fatigue may have been a factor in the present study, since the decrease of isometric force during the 7-s submaximal tetanic contraction induced by PES was significantly higher than during 7-s MVC (20.2 vs. 10.9%). O'Leary et al. [14] showed previously that tetanic force declined by 15% during a 7-s supramaximal indirect PES in dorsiflexor muscles. Direct PES evokes action potential in intramuscular nerve branches generating force directly by activation of motor axons. It is well known that during direct PES the current is applied extracellularly to the nerve endings with preferential activation of the large fast-twitch (type II) muscle fibers. These fast-twitch fibers have larger axons with much lower electrical resistance for a given externally applied electrical current. Fast-twitch muscle fibers show greater potentiation but are more sensitive to fatigue [10]. Therefore, the higher muscle fatigue immediately after the 7-s conditioning submaximal PES in comparison with 7-s MVC could explain the initial decay in PAP observed. This fatigue could be caused mainly by metabolic factors such as decreased pH and increased inorganic phosphate concentration [25]. These factors have been associated with the decreased sensitivity of regulatory proteins to Ca^{2+} during fatigue [1]. However, the present study showed that fatigue dissipated at faster rate than PAP. This could argue why 1 min after conditioning activation PAP did not differ significantly in both conditioning activations proposed.

In conclusion, this study indicated a significantly higher PAP in KE muscles immediately after a conditioning MVC compared with submaximal direct PES interspersed with similar moderate level PAP at 3 min after conditioning activations.

REFERENCES

1. Allen D. G., Lännergren J., Westerblad H. (1995) Muscle cell function during prolonged activity: cellular mechanisms of fatigue. Exp. Physiol. 80: 497–527
2. Broman H., De Luca C. J. (1985) Motor unit recruitment and firing rates interaction in the control of human muscles. Brain Res. 337: 311–319
3. Brown I. E., Loeb G. E. (1998) Post-activation potentiation–A clue for simplifying models of muscle dynamics. Am. Zool. 38: 743–754
4. Edwards R. H. T., Hill D. K., Jones D. A., Merton P. A. (1977) Fatigue of long duration in human skeletal muscle after exercise. J. Physiol. (Lond.) 272: 769–778

5. Feiereisen P., Duchateau J., Hainaut K. (1997) Motor unit recruitment order during voluntary and electrically induced contractions in the tibialis anterior. Exp. Brain Res. 114: 117–123
6. Grange R. W., Vandenboom R., Houston M. E. (1993) Physiological significance of myosin phosphorylation in skeletal muscle. Can. J. Appl. Physiol. 18: 229–242
7. Green H. J., Jones S. R. (1989) Does post-tetanic potentiation compensate for low frequency fatigue? Clin. Physiol. 9: 499–514
8. Hainaut K., Duchateau J. (1992) Neuromuscular electrical stimulation and voluntary exercise. Sports Med. 14: 100–113
9. Hamada T., Sale D. G., MacDougall J. D., Tarnopolsky M. A. (2000) Postactivation potentiation, fiber type, and twitch contraction time in human knee extensor muscles. J. Appl. Physiol. 88: 2131–2137
10. Hamada T., Sale D. G., MacDougall J. D., Tarnopolsky M. A. (2003) Interactions of fibre type, potentiation and fatigue in human knee extensor muscles. Acta Physiol. Scand. 178: 165–173
11. Houston M. E., Grange R. W. (1990) Myosin phosphorylation, twitch potentiation, and fatigue in human skeletal muscle. Can. J. Physiol. Pharmacol. 68: 908–913
12. MacIntosh B. R., Willis J. C. (2000) Force-frequency relationship and potentiation in mammalian skeletal muscle. J. Appl. Physiol. 88: 2088–2096
13. Moore R. L., Stull J. T. (1984) Myosin light chain phosphorylation in fast and slow skeletal muscle in situ. Am. J. Physiol. 247: C462–C471
14. O'Leary D. D., Hope K., Sale D. G. (1997) Posttetanic potentiation of human dorsiflexors. J. Appl. Physiol. 83: 2131–2138.
15. Palmer B. M., Moore R. L. (1989) Myosin light chain phosphorylation and tension potentiation in mouse skeletal muscle. Am. J. Physiol. 257: C1012–C1019
16. Petrella R. J., Cunningham D. A., Vandervoort A. A., Paterson D. H. (1989) Comparison of twitch potentiation in the gastrocnemius of young and elderly men. Eur. J. Appl. Physiol. 58: 395–399
17. Pääsuke M., Ereline J., Gapeyeva H. (1999) Neuromuscular fatigue during repeated exhaustive submaximal static contractions of knee extensor muscles in endurance-trained, power-trained and untrained men. Acta Physiol. Scand. 166: 319–326
18. Pääsuke M., Ereline J., Gapeyeva H. Twitch contraction properties of plantar flexor muscles in pre- and post-pubertal boys and men. Eur. J. Appl. Physiol. 82: 459–464

19. Rassier D. E., MacIntosh B. R. (2000) Coexistence of potentiation and fatigue in skeletal muscle. Braz. J. Med. Biol. Res. 33: 499–508
20. Requena B., Ereline J., Gapeyeva H., Pääsuke M. (2003) Twitch posttetanic potentiation of knee extensor muscles after brief high-frequency percutaneous submaximal electrical stimulation. Acta Kinesiol. Univ. Tart. 8: 106–116
21. Sawczuk A., Powers R. K., Binder M. D. (1995) Intrinsic properties of motoneurons. Implications for muscle fatigue. Adv. Exp. Med. Biol. 384: 123–134
22. Stuart D. S., Lingley M. D., Grange R. W., Houston M. E. (1988) Myosin light chain phosphorylation and contractile performance of human skeletal muscle. Can. J. Physiol. Pharmacol. 66: 49–54
23. Sweeney H. L., Stull J. T. (1986) Phosphorylation of myosin in permeabilized mammalian cardiac and skeletal muscle cells. Am. J. Physiol. 250: C657–C660
24. Vandenboom R., Grange R. W., Houston M. E. (1993) Threshold for force potentiation associated with skeletal myosin phosphorylation. Am. J. Physiol. 265: C1456–C1462
25. Vanderthommen M., Depresseux J. C., Bauvir P., Degueldre C., Delfiore G., Peters J. M., Sluse F., Crielaard J. M. (1997) A positron emission tomography study of voluntarily and electrically contracted human quadriceps. Muscle Nerve 20: 505–507
26. Vandervoort A. A., Quinlan J., McComas A. J. (1983) Twitch potentiation after voluntary contraction. Exp. Neurol. 81: 141–152
27. Yang Z., Stull J. T., Levine R. J. C., Sweeney H. L. (1998) Changes in interfilament spacing mimic the effects of myosin regulatory light chain phosphorylation in rabbit psoas fibers. J. Struct. Biol. 122: 139–148

Correspondence to:
Mati Pääsuke
Institute of Exercise Biology and Physiotherapy,
University of Tartu,
5 Jakobi Street,
51014 Tartu,
Estonia

Acta Kinesiologiae Universitatis Tartuensis, 2004, Vol. 9

MAXIMAL POWER OUTPUT DURING HALF-SQUAT LEG EXTENSION EXERCISE IN SEMI-PROFESSIONAL SOCCER PLAYERS

B. Requena[1, 3], T. Karu[2], H. Gapeyeva[1], J. Ereline[1], T. Kums[1], J.J. González-Badillo[3], M. Pääsuke[1]

[1] *Institute of Exercise Biology and Physiotherapy, University of Tartu, Estonia*

[2] *FC Tammeka, Tartu, Estonia*

[3] *Faculty of Sport, University Pablo de Olavide, Sevilla, Spain*

ABSTRACT

The present study evaluated the maximal power (MP) output during a half-squat concentric leg extension exercise with external (barbell) loads in soccer players by determining the load, velocity, displacement and force in which MP was attained. Power output characteristics were measured using Isocontrol Device (Madrid. Spain). Twenty two semi-professional soccer players with mean (±SD) age, height and body mass 22.4±2.6 years, 178.0±6.3 cm and 73.3±7.7 kg, respectively, participated in this study. The mean values of MP output and MP output relative to body mass during half-squat leg extension exercise in soccer players were 1153±257 W and 15.9±1.0 $W \cdot kg^{-1}$, respectively. Mean external load when MP output was attained in soccer players was 82.2±13.0 kg. Mean barbell displacement, force and velocity when MP output was attained were 23.1±3.9 cm, 1063±171 N and 1.06±0.12 $m \cdot s^{-1}$, respectively. A significant positive correlation was observed between the maximal force produced at the first external load and MP output ($r=0.52$, $p<0.01$). In conclusion, the present study indicated that MP output in half-squat concentric leg extension exercise in semi-professional soccer players is ~16 $W \cdot kg^{-1}$ and it is attained with external loads of 80–90 kg. This information can be used for compiling optimal power training programmes for soccer players.

Key words: muscle power, soccer, athletic training, skeletal muscles

INTRODUCTION

Soccer is the most popular sport in the world with hundreds of millions of people reported to play the game [3]. In the last years, numerous scientific papers have focused on the anthropometric and physiological characteristics of elite soccer players with the aim of giving clues to talent detection, identification and development programmes [13]. Nevertheless, few of these studies have been published in respect of explosive muscle strength (power) characteristics and in their majority have been surveyed in isokinetic devices [8, 11, 14]. However, many playing actions in soccer imply the generation of force at angular velocities higher than 5.2 $rad \cdot s^{-1}$ which is the upper limit for most of isokinetic devices. It has been demonstrated that the angular velocity of the lower leg is about 17.5 $rad \cdot s^{-1}$ during a football kick [2].

The ability of the neuromuscular system to produce explosive strength (power) appears to be critical in many sports, including soccer, which require optimal combinations of force and velocity of muscle contraction to maximize athletic performance [4]. Maximal power (MP) output is the highest power generated during a particular movement and is produced when both force and velocity are at optimum values. MP output during concentric isolated movements (e.g. elbow flexion) has been previously found to occur approximately at 1/3 of the maximal shortening velocity and at a force level of 30% of maximal isometric force and/or between loads of 30–45% of the one repetition maximum (1 RM) [6, 7, 10]. Recently, MP output has been studied during dynamic exercises used in strength and conditioning programmes (e.g. squat or bench press) [4, 5, 12, 15]. In general, MP output occurs between 50 and 70% of 1 RM in the half-squat leg extension exercise and between 40 and 60% in the bench press throwing exercise. However, significant differences have been observed in the load-power relationship between subjects with different athletic backgrounds. MP output during half-squat concentric leg extension exercise has been showed at the external load of 60% of the 1RM in handball players, middle distance runners and age-matched control subjects, and at the load of 45% of the 1 RM in weightlifters and road cyclists [4, 5]. However, there is a paucity of data on examining MP output of the leg extensor muscles in soccer players during traditional resistance training exercises.

The aim of the present study was to examine MP output during a half-squat concentric leg extension exercise with external (barbell) loads in semi-professional soccer players by determining the load, velocity, displacement and force in which MP was attained.

MATERIALS AND METHODS

Subjects

Twenty two semi-professional soccer players with mean (±SD) age, height and body mass of 22.4±2.6 years, 178.0±6.3 cm and 73.3±7.7 kg, respectively, participated in this study. All subjects were injury free at the time of testing. Full advice about possible risks and discomfort was given to the subjects and they all gave their written informed consent to participate. The experiment was approved by the Ethics Committee of the University of Tartu for Human Studies.

Apparatus and Experimental Procedure

Power output parameters during a half-squat concentric leg extension exercise with external (barbell) loads were measured using an Isocontrol Device (JLML I+D, Madrid, Spain, model 3.6) with custom-made software. The shoulders of the subjects were in contact with a bar of the barbell and the starting knee angle was 90°. On command "Go", the subject performed an explosive concentric leg extension from the flexed position to reach the full extension against the resistance determined by the weight plates added to both ends of the bar. The trunk was kept as straight as possible. The test was performed on a squatting apparatus in which the barbell was attached to both ends, with linear bearings on two vertical bars allowing only vertical movements.

The subjects were carefully familiarized with the test procedure and several submaximal and maximal half-squat concentric leg extensions with barbell loads were performed a few days before the measurements. Before testing, warm-up consisted of a set of 5 half-squat concentric leg extensions with loads of 40–50% of the perceived MP output. Thereafter, 4–5 separate single attempts were performed until the subject was unable to extend the legs to the required position. During the test, the first external (barbell) load selected was 20 kg interspersed with gradually increased loads by 10 kg until MP output was reached. The testing was terminated when the power output attained with the next load (e.g. 90 kg) was lower than that of the previous load (e.g. 80 kg) (Fig. 1). A 3-min rest between sets was employed. The following characteristics during the half-squat leg extension test were recorded by linking a rotatory encoder to the end part of the bar: MP output (W), and bar displacement (cm), velocity ($m \cdot s^{-1}$) and force (N) at which MP output was attained. The rotatory encoder recorded the position and direction of the bar within an accuracy margin of 0.0002 m.

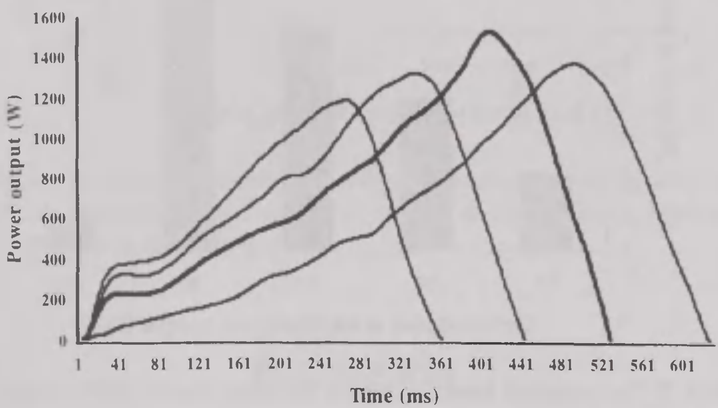

Figure 1. Power-time curves measured in one subject during half-squat leg extension exercise with external loads of 60, 70, 80 and 90 kg. The maximal power output in this subject was attained with external load of 80 kg.

Statistics

Data are expressed as means and standard deviations (±SD). Velocity and force values attained at the first external load were correlated with MP output value by using Pearson correlation (r). A level of $p<0.05$ was selected to indicate statistical significance.

RESULTS

The mean values of MP output and MP output relative to body mass during half-squat concentric leg extension exercise in soccer players were 1153±257 W and 15.9±1.0 W · kg^{-1}, respectively. Figure 2 shows the external (barbell) load in which MP output was attained in the

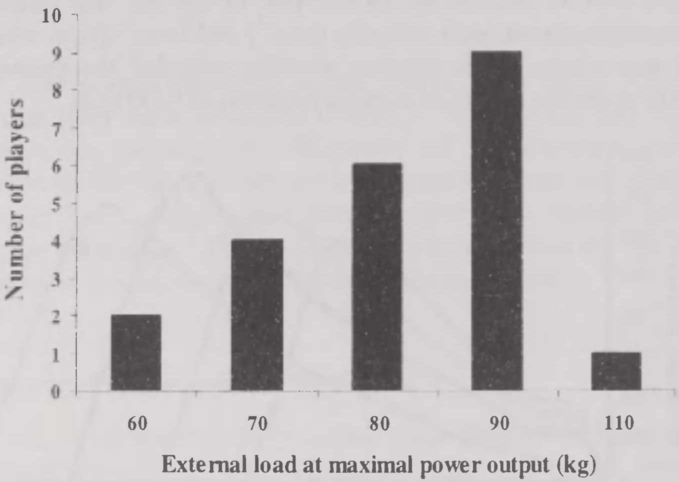

Figure 2. The external loads in which maximal power (MP) output was attained during half-squat leg extension exercise in semi-professional soccer players. Mean external load in measured group when MP was reached was 82.2±13.0 kg.

measured subjects. In the measured group of soccer players, mean external load when MP output was attained was 82.2±13.0 kg. Mean barbell displacement, force and velocity when MP output was attained were 23.1±3.9 cm, 1063±171 N and 1.06±0.12 m · s^{-1}, respectively. There was no significant correlation between maximal velocity and power output at the first measured external load and MP output. However, a significant positive correlation was observed between the maximal force produced at the first external load and MP output ($r = 0.52$, $p<0.01$) (Fig. 3).

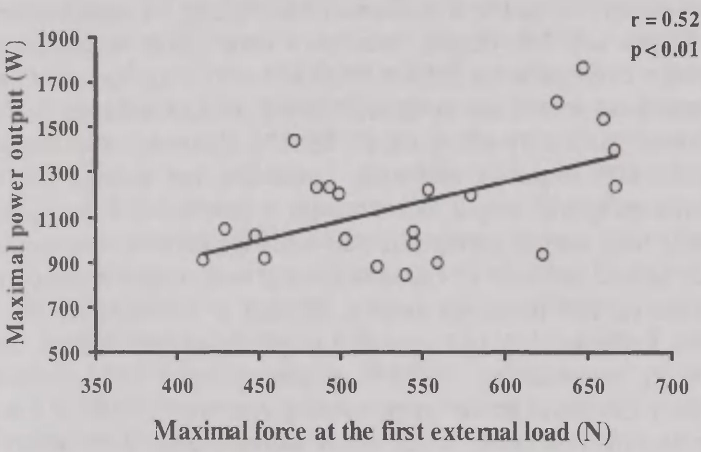

Figure 3. Correlation between maximal power output and maximal force at the first measured external load during half-squat leg extension exercise in semi-professional soccer players.

DISCUSSION

Muscle power (explosive strength) is important in many playing actions in soccer (e.g. tackling, jumping, kicking, short maximum sprints, turning and changing pace). The relationship between improvement in power output of the lower limb muscles and enhanced athletic performance is a simple concept. Recently, in team sports athlete's MP output in half-squat concentric leg extension exercise has been strongly negatively correlated with 5-m sprint time (r = –0.68) [16]. Young et al. [18] reported a strong negative correlation (r = –0.74) between 2.5-m sprint time and average power in jump squat exercise with an external load of 19 kg. However, the application of power output to the practical setting is not well established. The main purpose of the present study was to examine the MP output performed in half-squat concentric leg extension exercise in a group of semi-professional soccer players. The results obtained showed that: (1) mean external load in the measured group of soccer players when MP was attained was 82.2 kg, (2) absolute value of MP output and MP output relative to body mass in half-squat leg extension exercise were 1153.4 W and 15.9 $W \cdot kg^{-1}$, respectively. In general, these results are in agreement with previous studies performed in athletes from different sports [4, 16, 17]. However, only few studies assessed MP output in half-squat concentric leg extension exercise. Differences in MP output measurement procedure such as the type of exercise used during testing (i.e. half-squat leg extension vs. jump half-squat) or the methods of calculating of power output (average power per load vs. MP per load) make it difficult to compare the published results. Baker et al. [1] showed that in power-trained athletes loads of 85–90 kg, representing 55–59% of the full-squat 1RM, evoked the highest mechanical power output during concentric phase of the squat jump exercise. However, in the above mentioned study the mean value of MP output was higher than that observed in the present study (1726 vs. 1153 W). Sleivert and Taingahue [16] also showed a higher MP output relative to body mass in rugby and basketball players (17.6 vs. 15.9 $W \cdot kg^{-1}$ in the present study). These differences can be partly explained with the different types of exercise used for testing (half-squat jump vs. half-squat leg extension). It has been shown that a half-squat jump does not entail a large deceleration period as occurs during the half-squat leg extension exercise [10]. Consequently, maximal half-squat jump results in greater power output, velocity, and muscle activation level compared with its traditional strength training counterpart, i.e. half-squat concentric leg extension [9, 10]. Also, a great inter-individual variability in external (barbell) load in which MP output was attained was observed in the present study (Fig. 2). The present data confirm that soccer players may not need to have an extraordinary capacity within any of the areas of physical performance, whereas they are in agreement with previous studies which indicated a marked differences in physiological characteristics among top soccer players [13].

Izquierdo et al. [4] showed that in weightlifters and handball-players, the velocities when MP output of the lower extremities has been attained were higher (1.06 and 0.96 m · s^{-1}, respectively) than those recorded for road cyclists and middle distance runners (0.75 and 0.72 m · s^{-1}, respectively). In the present study, MP output in semi-professional soccer players was attained a similar velocity that was previously shown in weightlifters (1.06 m · s^{-1}). This similarity in power production of the lower limbs in weightlifters and soccer players can be partly explained with long-term adaptation to explosive strength training. Soccer training sessions and competitive games are composed of frequent strenuous activities of the lower limbs muscles such as short sprint accelerations and repetitions of various kicks. Additionally, we observed that MP output was performed at 23.1 cm of displacement from the initial position (90° of knee flexion). No previous studies measured displacement at which MP output was attained. In the present study, this displacement was not correlated significantly with the players' height ($r=0.34$, $p>0.05$). This could be explained in the homogeneity height of the sample selected (coefficient of variation (CV) was 3.3%). However, in contrast with the heterogeneity observed in MP values (CV was 11.5%), the velocity at which MP was attained was similar for all the measured subjects.

We found no significant correlations between maximal velocity and power output at the first external load (20 kg), and MP output in half-squat leg extension exercise in soccer players. However, a significant positive correlation was observed between the maximal force at first external load and MP output ($r=0.52$). Subjects with higher maximal force value at lowest external resistance tended to have greater MP output (Fig. 3). This can be partly explained by the homogeneity showed in the velocity at which MP output was attained. Thus, if the subjects with similar velocity can generate more force then they will also reach higher MP values.

In conclusion, the present study indicated that MP output in half-squat concentric leg extension exercise in semi-professional soccer players is ~16 W · kg^{-1} and it is attained with loads of 80–90 kg. This information can be used for compiling optimal power training programmes for soccer players.

REFERENCES

1. Baker D. (2001) The load that maximizes the average mechanical power output during jump squats in power-trained athletes. J. Strength Cond. Res. 15: 92–97
2. Dorge H. C., Andersen T. B., Sorensen H., Simonsen E. B., Aagaard H., Dyhre-Poulsen P., Klausen K. (1999) EMG activity of the iliopsoas muscle and leg kinetics during the soccer play kick. Scand. J. Med. Sci. Sports. 9: 195–200
3. Hillis S. (1999) Preparations for the World Cup. Brit. J. Sport Med. 32: 95
4. Izquierdo M., Häkkinen K., Gonzalez-Badillo J. J., Ibanez J., Gorostiaga E. (2002) Effects of long-term training specificity on maximal strength and power of the upper and lower extremities in athletes from different sports. Eur. J. Appl. Physiol. 87: 264–271
5. Izquierdo M., Ibanez J., Häkkinen K., Kraemer W.J., Ruesta M., Gorostiaga E.M. (2004) Maximal strength and power, muscle mass, endurance and serum hormones in weightlifters and road cyclists. J. Sports Sci. 22: 465–478
6. Kaneko M., Fuchimoto T., Toji H., Suei K. (1983) Training effect of different loads on the force-velocity relationship and mechanical power output in human muscle. Scand. J Sports Sci. 5: 50–55
7. Mastropalo J. A. (1992) A test of maximum power stimulus theory for strength. Eur. J Appl. Physiol. 65: 415–420
8. Masuda K., Kikuhara N., Hideyuki T., Yamanaka K. (2003) The relationship between muscle cross-sectional area and strength in various isokinetic movements among soccer players. J. Sports Sci. 21: 851–858
9. Newton R., Kraemer W., Häkkinen H., Humphries B., Murphy A. (1996) Kinematics, kinetics and muscle activation during explosive upper body movements. J. Appl. Biomech. 12: 31–43
10. Newton R. U., Murphy A. J., Humphries B. J., Wilson G. J., Draemer W. J., Häkkinen K. (1997) Influence of load and stretch shortening

cycle on the kinematics, kinetics and muscle activation that occurs during explosive upper-body movements. Eur. J. Appl. Physiol. 75: 333–342

11. Oberg B., Moller M., Gillquist J., Ekstrand J. (1986) Isokinetic torque levels for knee extensors and knee flexors in soccer players. Int. J. Sports Med. 7: 50–53
12. Rahmani A., Viale F., Dalleau G., Lacour J.-R. (2001) Force/velocity and power/velocity relationships in squat exercise. Eur. J. Appl. Physiol. 84: 227–232
13. Reilly T., Bangsbo J., Franks A. (2000) Anthropometric and physiological predispositions for elite soccer. J. Sports Sci. 18: 669–683
14. Rochcongar P., Morvan R. Jan J., Dassonville J. Beillot J. (1988) Isokinetic investigation of the knee extensors and knee flexors in young French soccer players. Int. J. Sports Med. 9: 448–450
15. Siegel J. A., Gilders R. M., Staron R. S., Hagerman F. C. (2002) Human muscle power output during upper- and lower-body exercises. J. Strength Cond. Res. 16: 173–178
16. Sleivert G., Taingahue M. (2004) The relationship between maximal jump-squat power and sprint acceleration in athletes. Eur. J. Appl. Physiol. 91: 46–52
17. Stone M. H., O'Bryant H. S., McCoy L., Coglianese R., Lehmkuhl M., Schilling B. (2003) Power and maximum strength relationships during performance of dynamic and static weighted jumps. J. Strength Cond. Res. 17: 140–147
18. Young W., McLean B., Ardagna J. (1995) Relationship between strength qualities and sprinting performance. J. Sports Med. Phys. Fitness 35: 13–19

Correspondence to:
Bernardo Requena
Institute of Exercise Biology and Physiotherapy,
University of Tartu,
Jakobi 5, Tartu 51014
Estonia

Acta Kinesiologiae Universitatis Tartuensis, 2004, Vol. 9

THE EFFECT OF 3-MONTH SCHALOW COORDINATION DYNAMIC THERAPY ON MOVEMENT COORDINATION CHARACTERISTICS OF THE LIMBS IN SUBJECTS WITH CEREBRAL PALSY

P. Jaigma[1,2], G. Schalow [1,2], M. Pääsuke[1]
[1]*Institute of Exercise Biology and Physiotherapy, University of Tartu, Tartu, Estonia*
[2]*Coordination Dynamics Therapy Laboratory, Tallinn, Estonia*

ABSTRACT

The present study evaluated the effect of 3-month Schalow coordination dynamic therapy on movement coordination between arms and legs in patients with cerebral palsy (CP). Six CP patients (5 females and 1 male) and 24 healthy subjects aged 8–27 years participated in this study. The coordination dynamics therapy included exercising on a Giger MD treatment device, crawling, treadmill walking and jumping on springboard twice per week and 2 hours per day. The movement coordination of the limbs was evaluated by the arrhythmicity of exercising on the mentioned device, whereas the frequency of exercising was also assessed. Before therapy, the arrhythmicity of forward and backward exercising was higher ($p<0.001$) and the frequency of exercising was lower ($p<0.001$) in CP patients than in controls. After 3-month therapy, CP patients demonstrated a significant decrease ($p<0.01$) in the arrhythmicity of forward and backward exercising (49 and 46%, respectively) and an increase ($p<0.05$–0.01) in the frequency of exercising when compared with the pre-treatment level. However, in CP patients the arrhythmicity of forward and backward exercising remained higher ($p<0.001$) and the frequency of exercising remained lower ($p<0.001$) after the treatment as compared to controls. It was concluded that in CP patients 3-month Schalow coordination dynamics therapy markedly improved movement coordination between arms and legs.

Key words: cerebral palsy, movement coordination, coordination dynamics therapy

INTRODUCTION

Cerebral palsy (CP) is an umbrella term covering a group of non-progressive motor impairment syndromes secundary to lesion or anomalies of the brain arising in the early stages of its development [9]. The factors related to the impaired motor function in CP children are spasticity, paresis, lack of motor control in the affected limb, and dystonia. Muscle function often becomes progressively more compromised in CP, leading to reduced mobility [2]. The condition has become more complex over the last 20 years with the increasing survival of children born at less than 28 to 30 weeks gestational age. In recent years understanding of the motor impairment in CP patients has increased, but less is known about effects of therapy. Evidence suggests that therapy can improve functional performance in subjects with CP but it is inconclusive as to which approach might be the most beneficial. The therapist has to understand the interaction of all systems, cognitive/perceptual, motor, musculoskeletal, sensory and behavioral, in the context of the development and plasticity of the central nervous system (CNS). It is necessary to understand the limitations of the damaged immature nervous system and optimize the functional performance of the patients [7].

Following CNS injury, the phase and frequency coordination between neuron firing and the oscillatory firing of the neuronal network organization of the human central nervous system (CNS) becomes impaired [11, 19]. Movement therapy has been developed by starting with the restoration of the coordinated firing of neurons and neuron assemblies: this therapy has been termed coordination dynamics therapy by G. Schalow [12, 13, 14]. Up to date coordination dynamics therapy is movement therapy in which the CNS learns to improve its functioning by learning the improvement of phase and frequency coordination between neuron firing upon exercising on a special coordination dynamics therapy device and by learning or re-learning automatisms, old-learned movements, and rythmic dynamic stereotyped movements like creeping, crawling, up-righting, walking, running, jumping on springboard, and climbing staircases [20]. The progress of therapy is quantified by the improvement of the coordination between arm and leg movements. The aim of this movement therapy is to repair the lesioned CNS functionally, and partially also structurally by learning [20]. So far substantial improvement or partial cure of CNS functioning was achieved in the case of stroke [14], traumatic brain injury [12], spinal cord injury [13, 15] and Parkinson's disease [21].

The aim of this study was to evaluate the effect of 3-month low intensity Schalow coordination dynamic therapy on movement coordination of the limbs in CP patients. More specifically, we were interested in the assessment of arrhythmicity of forward and backward exercising and the frequency of exercising on the therapy device in CP patients before and after therapy, whereas patients were compared with healthy control subjects.

MATERIALS AND METHODS

Subjects

Six CP patients (5 females and 1 male) participated in this study. The patients were 8, 10, 14, 18, 19 and 27 years old. Five patients could walk with support (sticks or walking frame) and one subject could walk independently but had balance problems. None of them could run. All the patients were free from the limitation of range of motion in joints of upper or lower limbs. The control group included 24 healthy subjects

(20 females and 4 males). Similar to CP patients, they were 8, 10, 14, 18, 19 and 27 years old (4 subjects per each age). The study was approved by the Ethics Committee for Human Studies of the University of Tartu. The physical characteristics of the subjects are described in Table 1.

Table 1. The physical characteristics of the subjects

Subjects	Gender	Age (yrs)	Height (cm)	Body mass (kg)	BMI ($kg \cdot m^{-2}$)
CP patients					
1.	M	8	125.0	28.8	18.5
2.	F	10	125.5	22.8	14.5
3.	F	14	175.0	67.8	22.2
4.	F	18	157.7	45.0	18.3
5.	F	19	176.0	79.9	25.8
6.	F	27	162.5	50.9	19.3
Mean ±SE		15.8±2.8	153.6±9.4	49.2± 9.0	19.7±1.6
Controls	(n=24)				
Mean ±SE		16.1±1.3	154.9±3.7	48.1±2.8	20.0±0.5

Apparatus and Experimental Procedure

During testing of the movement coordination between arms and legs and during coordination dynamic therapy the subjects were exercising in the sitting (Fig. 1A) and lying (Fig. IB) position on Giger MD measuring and therapy device (Switzerland). The subjects' feet were placed and fixed on pedals in a comfortable position and the hands were holding the levers. The therapy device was connected to a personal computer. The device imposes changing phases between arm and leg movements including pace and trot gait coordination. The movement coordination was assessed by the arrhythmicity (s^{-2}) of forward and backward exercising. The frequency of exercising (Hz) was also assessed. The variation of the frequency of turning movements and its time derivative (the coordination dynamics value) quantifies the quality of CNS organization [17, 18]. The total measuring time was 20 min including 10 min forward exercising interspersed with 5 min backward and again 5 min forward turning. All patients were instructed to turn as smoothly as possible with an individually matched speed. Figure 1C,D shows an original recording of the frequency and arrhythmicity of forward exercising for one of the patients before and after therapy.

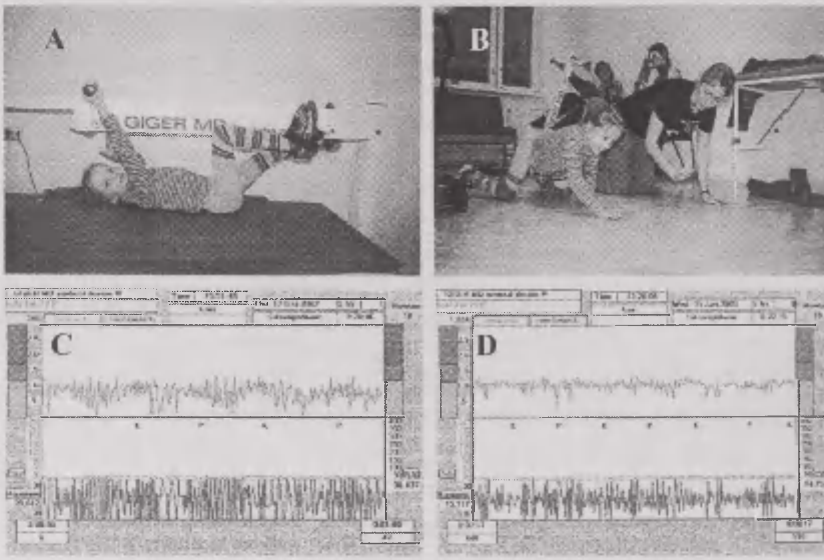

Figure 1. Giger MD measuring and therapy device (A), crawling in interpersonal coordination (B), and arrhythmicity of exercising at the beginning (D) and end (E) of therapy for one patient.

The 3-month coordination dynamics therapy for CP patients was performed by the same physiotherapist according to the instructions of professor G. Schalow. The therapy included coordinated arm and leg movements on a therapy device (Fig. 1A), crawling (Fig. 1B), treadmill walking and jumping on springboard twice per week and 2 hours per day. The patients were measured before and after therapy. The control group was measured once.

Statistical Analysis

Data are expressed as mean ± SE. The comparison between pre- and post-treatment testing was conducted using a one-tail Student's paired t-test. Independent two-tail Student's t-test was used to measure the differences between CP patients and controls. A level of $p<0.05$ was selected to indicate statistical significance.

RESULTS

No significant differences in mean values of height, body mass and body mass index were observed between the groups of CP patients and healthy control subjects (Table 1). The mean values of arrhythmicity in forward and backward exercising in CP patients and controls are presented in Fig. 2 and mean frequency of turning in Fig. 3. Before therapy, the arrhythmicity in forward and backward exercising was higher ($p<0.001$), and the frequency of exercising was lower ($p<0.001$) in CP patients than controls. After 3-month Schalow coordination dynamic therapy, CP patients demonstrated a significant decrease ($p<0.01$) in arrhythmicity in forward and backward exercising and an increase ($p<0.05$–0.01) in the frequency of exercising when compared with the pre-treatment level. However, in CP patients the arrhythmicity in forward and backward exercising remained higher ($p<0.001$) and the frequency of exercising remained lower ($p<0.001$) after treatment as compared to controls.

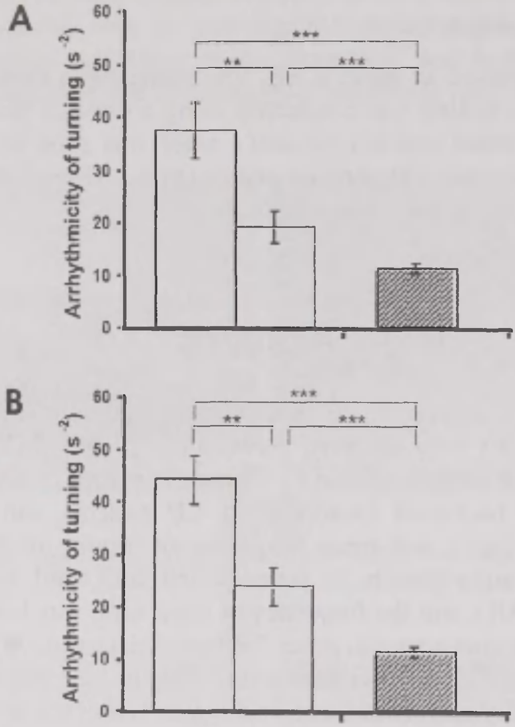

Figure 2. Mean (±SE) values of arrhythmicity in forward (A) and backward (B) exercising in patients with cerebral palsy (CP) and controls. ** p<0.01; *** p<0.001.

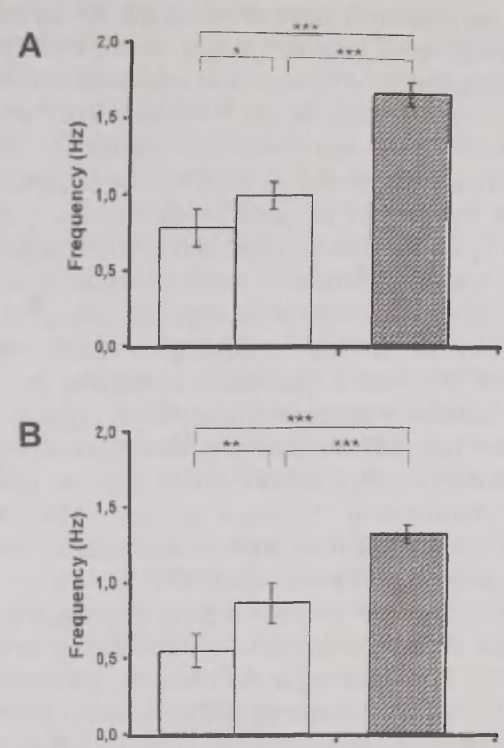

Figure 3. Mean (±SE) values of turning frequency in forward (A) and backward (B) exercising in patients with cerebral palsy (CP) and controls. * p<0.05; *** p<0.001.

DISCUSSION

The coordination between arm and leg movements is strongly impaired in subjects with CNS injuries like in stroke [14], spinal cord injury [13, 15], and traumatic brain injury [12]. The results of the present study are in agreement with previous studies indicating that coordination between arm and leg movements is impaired also in CP patients [7, 20, 23]. Low-intensity (4 hours per week) Schalow coordination dynamics therapy with the duration of 3 months decreased the arrhythmicity of forward and backward exercising on therapy device by 49% and 46%, respectively. The frequency of forward and backward exercising in CP patients was significantly increased after therapy. Thus after 3-month therapy the frequency of forward exercising increased by 27% and the frequency of backward exercising by 56%. However, these values in CP patients were by far not as good as the control group values, consequently these patients showed improvement but much more has to be done to achieve normal values. In previous studies it was reported that with 3-month intensive coordination dynamics therapy the decrease of the arrhythmicity of forward exercising in stroke patients was approximately 70% [14] and in patients who suffered from traumatic brain injury the decrease was approximately 69% [12]. In one case a female patient who had suffered severe poliomyelitis at the age of 1 year lost all the motor functions below Th 10. Thirty six years later she began with the coordination dynamics therapy. After 3 years of intensive therapy, her leg functions were re-appearing (re-innervation), the legs started to grow and menisci were built [18].

It also seems that with low intensity therapy it is possible to achieve some improvement in the coordination of arm and leg movements in CP patients. Due to injury the organization of the movement patterns becomes pathologic because of the injured (destroyed) CNS parts, the impaired coordinated firing of neurons with respect to time and space (loss of relative phase and frequency coordination), and the impaired integrativity of CNS organization. It has been reported that motor unit firing is lower in subjects with CP [10]. If the CNS has only been impaired by a minor injury, then the CNS may be able to repair itself. However, if a patient suffered a severe CNS injury then the CNS cannot repair the basic functional structure by itself. Instrumented supervised re-learning offers the injured CNS neuronal networks dynamic physiologic sets of phase relation, evolving with time, for re-learning [18]. The repair by learning is mainly achieved by (1) improving the coordinated firing of neurons up to a few milliseconds in the human CNS, (2) exercising movements deeply build in the CNS like automatisms and old learned movements and (3) exercising rhythmic dynamic stereotyped movements (like jumping in the springboard).

The change of the coordination dynamics is achieved by the coordination dynamic therapy which uses the strategies (1) of accurate movements coordinated up to a few milliseconds by supervised instrumented learning to reconnect functionally disconnected neuronal network parts, (2) increasing the integrity of coordinated movements or behaviors to repair integrated CNS functions like higher mental functions, (3) of enhancing movement-induced afferent input to stabilize physiologic network states of lesioned CNS and to destabilize pathologic network state like spasticity by offering more physiologic afferent input to the lesioned neuronal networks for physiologic self-organization, and by supplying — through instrumented coordinated movements — physiologic regulation (motor control) to the networks by using receptors of the periphery, especially the secondary muscle spindle afferents, and (4) of going to the limits of exercising by increasing the intensity of the therapy to force the "adaptive machine" CNS to adapt [18].

It is well known that in case of CP there is lack of reciprocal inhibition between antagonistic muscles [5, 8]. Bobath [1] was suggesting that one of the problems for the patient with increased tone was excessive co-contraction which resulted in stiffness and slow, difficult movements for function. In our study it can be assumed that the coordination between antagonistic muscles improved, because there was a significant increase in the exercising frequency and the exercising became much smoother. In everyday life it is very important to have well coordinated muscle activity and well coordinated arm, leg, and trunk movements during different tasks.

It is also possible that the inappropriate co-contraction of agonist and antagonist muscles results from altered biomechanical alignment in addition to abnormal neural control of reciprocal inhibitory circuits between the muscle pair [23]. Neurotherapists must therefore consider biomechanical principles in the assessment and management of a neurologically impaired individual.

It has been reported that oscillatory formation training changes efficiencies of synapses [4, 22] to allow more physiologic self-organization at different levels of network organization. Synaptic plasticity will work at the single neuron level, at the neuron assembly level (premotor and propriospinal oscillatory firing subnetworks), and at the macroscopic network level with functional output [16].

In brain lesions, the principal cause of movement disabilities is the loss of strength and control resulting from the lesion [3]. From the Neuronal Group Selection Theory (NGST) point of view, children with pre- or perinatally acquired brain damage, such as children with CP and part of the children with developmental coordination disorder, suffer from stereotyped motor behavior, produced by a limited repertoire or primary (sub)cortical neuronal networks. These children have also problems in selecting the most efficient neuronal activity, due to deficits in the processing of sensory information. Therefore, NGST suggests that intervention in these children at an early age should be aimed at the enlargement of the primary neuronal networks. With increasing age, the emphasis of intervention could shift to the provision of ample opportunities for active practice, possibly compensating for the impaired selection [6].

In conclusion, the present study demonstrated that 3-month Schalow coordination dynamics therapy program improved the movement coordination of arms and legs assessed by the arrhythmicity of exercising on a treatment device. The frequency of exercising (cyclic movements) was also increased. However, after 3-month therapy the CP subjects had not reached the values of healthy subjects. For therapists it is important to decide which kind of therapy the patient should get. In case of CNS injuries the exercise therapy methods which take into account the organization principles of the CNS itself are very promising and have very little risks. If we know how the human CNS organizes itself, then we may find ways to change the self-organization with therapy, thus reorganizing the CNS and securing the best outcome possible for the patient.

REFERENCES

1. Bobath B. (1990) Adult hemiplegia: evaluation and treatment, 3rd ed. Heimann Medical Books, London

2. Booth C. B., Cortina-Borja M. J., Theologis T. N. (2001) Collagen accumulation in muscles of children with cerebral palsy and correlation with severity of spasticity. Dev. Med. Child Neurol. 43: 314–320
3. Carr J. H., Sheperd R. B., Ada L. (1995) Spasticity: Research findings and implications for intervention. Physiotherapy 81: 421–429
4. Eccles J. C. (1979) Synaptic plasticity. Naturwiss. 66: 147–153
5. Gibbs J., Harrison, L. M., Stephens J. A. (1999) Does abnormal branching of inputs to motor neurons explain abnormal muscle co-contraction in cerebral palsy? Dev. Med. Child Neurol. 41: 465–472
6. Hadders-Algra M. (2001) Early brain damage and the development of motor behavior in children: clues for therapeutic intervention? Neural Plast. 8: 31–49
7. Mayston M. J. (2001) People with cerebral palsy: effects of and perspectives for therapy. Neural Plast. 8: 51–69
8. Mayston M. J., Harrison L. M., Stephens J. A. (1996) Co-contraction of antagonistic muscles during development and in children with cerebral palsy. J. Physiol. (Lond.) 494: 67P
9. Mutch L., Alberman E., Hagberg B., Kodama K., Perat M. (1992) Cerebral palsy epidemiology: Where are we now and where are we going? Dev. Med. Child Neurol. 34: 547–551
10. Rose J., McGill K. C. (1998) The motor unit in cerebral palsy. Dev. Med. Child. Neurol. 40: 270–277
11. Schalow G. (1993): Spinal oscillators in man under normal and pathologic conditions. Electromyogr. Clin. Neurophysiol. 33: 409–426
12. Schalow G. (2002a) Improvement after traumatic brain injury achieved by coordination dynamic therapy. Electromyogr. Clin. Neurophysiol. 42: 195–203
13. Schalow G. (2002b) Recovery from spinal cord injury achieved by three month of coordination dynamics therapy. Electromyogr. Clin. Neurophysiol. 42: 367–376
14. Schalow G. (2002c) Stroke recovery induced by coordination dynamic therapy and quantified by the coordination dynamic recording method. Electromyogr. Clin. Neurophysiol. 42: 85–104
15. Schalow G. (2003) Partial cure of spinal cord injury achieved by 6–13 month of coordination dynamic therapy. Electromyogr. Clin. Neurophysiol. 43: 281–292
16. Schalow G., Zäch G. A. (1996) Spinal Locomotion. Gen. Physiol. Biophys. 15, Suppl. 1: 1–220

17. Schalow G., Zäch G. A. (1999): Koordinationsdynamik-Therapie als Lernprozess. Physiotherapie 2: 6–23
18. Schalow G., Zäch G. A (2000) Reorganization of human CNS. Gen. Physiol. Biophys. 19, Suppl. 1: 11–240
19. Schalow G., Bersch U., Michel D., Koch H. G. (1995) Detrusor-sphincteric dyssynergia in humans with spinal cord lesions may be caused by a loss of stable phase relations between and within oscillatory firing neuronal networks in the sacral micturition center. J. Auton. Nerv. Syst. 52: 181–202
20. Schalow G., Jaigma P., Kolts I. (in press) Cerebral palsy improvement achieved by coordination dynamics therapy. Electromyogr. Clin. Neurophysiol.
21. Schalow G., Pääsuke M., Ereline J., Gapeyeva H. (2004) Improvement in Parkinson's disease patients achieved by coordination dynamic therapy. Electromyogr. Clin. Neurophysiol. 44: 67–73
22. Tsukahara N. (1981) Synaptic plasticity in the mammal central nervous system. Ann. Rev. Neurosci. 4: 351–379
23. Woollacott, M. H., Burtner P. (1996) Neural and musculoskeletal contributions to the development of stance control in typical children and children with cerebral palsy. Acta Paed. Scand. Suppl. 416: 58–62

Correspondence to:
Piret Jaigma
Institute of Exercise Biology and Physiotherapy,
University of Tartu,
5 Jakobi Street, 51014 Tartu,
Estonia

USE OF CARDIOPULMONARY TESTING FOR DETECTION OF AEROBIC CAPACITY IN BASKETBALL PLAYERS

A. Gocentas[1], **A. Landõr**[2], **A. Juozulynas**[3]
[1, 3]*Department of Rehabilitation,*
Institute of Experimental and Clinical Medicine
Vilnius University, Lithuania
[2] *Department of Sports Medicine and Rehabilitation,*
University of Tartu, Estonia

ABSTRACT

Objective. The objective of this study was to investigate the aerobic capacity and cardiorespiratory endurance of basketball players before the season during cardiopulmonary exercise test (CPET).

Material and Methods. The material of the study was collected during a ramp exercise test of players from a leading Lithuanian basketball club. Fifteen professional male basketball players performed a ramp test (30W/min) on a cycle ergometer. Power output (P), heart rate (HR), ventilation (VE) and gas exchange indices were measured during the tests.

Results. The mean values of VO_{2max}, P_{max}, HR_{max} during CPET were 49.83±7.59 ml/kg/min, 368.67 W and 170.93±8.66 bpm, respectively. The mean value of VE_{max} was 138.15±25.18 l/min. The mean values of VO_{2AT}, P_{AT} and HR_{AT} during CPET were 54.1% of VO_{2max}, 50.8% of P_{max}, and 74.6% of HR_{max}, respectively. We found statistically significant correlations between all the main parameters of cardiopulmonary testing at anaerobic threshold.

Conclusions. The data of incremental CPET give reliable information about the aerobic performance of basketball players. There were statistically significant correlations between all the main parameters of CPET at anaerobic threshold. The collected data could become a reference source for sport and might be useful for monitoring and evaluating of present and future players.

Key words: basketball, physiological indices, oxygen uptake, cardiopulmonary testing

INTRODUCTION

Professional sports represent most extreme stress to which the body can be exposed. The main reason for preparticipation evaluation is to identify dangerous or disqualifying medical conditions. Usually, cardiopulmonary exercise testing is part of examination before involving athletes in training or competition. Cardiovascular stress test, using bicycle exercise with ECG registration and gas analysis, is currently employed not only for exclusion of disqualifying medical conditions but also for determining cardiorespiratory endurance. Basketball as a sport may be defined as high intensity intermittent exercise with considerable stress on the oxygen delivery system [5]. Although anaerobic metabolism plays a dominant role in basketball, we cannot underestimate the benefits of high aerobic performance for basketball players [4, 7]. Increase in aerobic fitness could enhance recovery from anaerobic bouts by supplementing anaerobic energy during exercise and by providing aerobically derived energy [3, 7, 14]. Maximal oxygen consumption is the primary measure of exercise capacity. Oxygen delivery by the blood flow has been considered the most important limiting factor in exercise.

Despite the long history of basketball, there is a paucity of information concerning the aerobic capacity of basketball players during cardiopulmonary exercise testing (CPET).

The purpose of this study was to determine the aerobic capacity, cardiorespiratory endurance and the relationships between the main characteristics during cardiopulmonary exercise testing in basketball players.

MATERIAL AND METHODS

Fifteen professional male basketball players with international experience (European Cups) participated in this study after being informed of all procedures, risks, and stresses and after providing their written consent. The experimental procedures and the study protocol conformed to the principles of the Declaration of Helsinki and were approved by the local Human Ethics Committee of Vilnius University. The examined athletes were members or potential candidates of a leading Lithuanian basketball club. Cardiopulmonary testing was performed as part of biomedical examination before the season. Each subject was well rested before the test and had not performed hard physical work during the preceding 24 hours. The good health of each subject was confirmed by a routine physical examination. None of the participants was taking any banned drugs, which could artificially improve his performance.

The morphological indices of the participants were determined. Standing height was measured without shoes to the nearest 1.0 cm using a stadiometer, model 220 (Seca, Germany). Body weight was measured to the nearest 0.1 kg using electronic digital scales, model 770 (Seca, Germany). Body mass index (BMI) of the participants was calculated.

Each subject performed an exercise test on the electrically braked cycle ergometer Ergometrics 800 (Ergoline, Bitz, Germany). Power output was increased by 30 W at every minute and pedalling cadence was kept constant at 60–70 rpm. Exercise tests were terminated until exhaustion or when the established criteria of test termination were met. Termination of the test was associated with the following criteria: respiratory exchange ratio being 1.10 or higher, heart rate and VO_2 attaining a plateau with increasing workload, leg discomfort and patient fatigue. All subjects completed the test protocol without any adverse effects.

Gas exchange data were collected continuously using the automated breath by breath analysis system Vmax229C (Sensormedics Corp., Yorba Linda, CA, USA). Calibration of the flow/volume sensor was achieved immediately before each test by manually pumping a 3-litre syringe through the flow meter at a rate similar to that achieved during the exercise test.

Heart rate was measured with the Corina electrocardiograph (model 7803A) with standard electrode placement.

In all 15 subjects, the following variables were sampled: power output at the peak of exercise (P_{max}) and power output at anaerobic threshold (P_{AT}) in watts (W), minute ventilation at rest (VE_{rest}), at anaerobic threshold (VE_{AT}) and at the peak of exercise (VE_{max}) in l/min, oxygen consumption at rest (VO_{2rest}), at anaerobic threshold (VO_{2AT}) and maximal oxygen consumption (VO_{2max}) in ml/kg/min, the ratio of oxygen consumption at anaerobic threshold to maximal oxygen consumption (VO_{2AT}/VO_{2max}), relationship between oxygen uptake and work rate (VO_2max/W), respiratory quotient (RQ), heart rate at rest (HR_{rest}), at anaerobic threshold (HR_{AT}) and at the peak of exercise (HR_{max}) in beats per minute (bpm).

The Kolmogorov-Smirnov test was applied to establish the Gaussian distribution of the variables. The data are reported as means and 95% confidence intervals (CI). Spearman correlation coefficients were used to determine the relationships between dependent variables. The level of significance was set at $p<0.05$.

RESULTS

The anthropometric parameters of the subjects are presented in Table 1.

Table 1. Anthropometric indices of the study subjects.

Index	Mean	Minimum	Maximum	Standard deviation
Age (years)	22.93	19.00	29.00	3.20
Height (cm)	196.53	182.00	209.00	8.42
Body mass (kg)	93.37	71.50	111.00	11.19
Body mass index (kg/m^2)	24.11	20.45	26.18	1.81

The differences in the morphologic indices can be attributed to their position on the field (center, forward or defence player).

The functional parameters of the participants are presented in Table 2.

Table 2. Functional indices of the study subjects.

Nr	Index	Mean±SD	Median	Minimum	Maximum
1.	VO_2max (ml/kg/min)	49.83±7.59	50.5	35.6	63.8
2.	VO_{2AT} (ml/kg/min)	26.45±3.62	26.7	19.8	31.7
3.	VO_2rest (ml/kg/min)	5.63±1.09	5.7	4.0	8.1
4.	Pmax (W)	368.67±48.75	353.4	300	450
5.	P_{AT} (W)	187.53±45.03	201.7	101	300
6.	HRrest (bpm)	70.87±12.03	68	44	92
7.	HR_{AT} (bpm)	127.67±11.36	130	110	149
8.	HRmax (bpm)	170.93±8.66	172	151	183
9.	VErest (l/min)	16.89±3.55	16.2	11.1	23.5
10.	VE_{AT} (l/min)	56.71±10.55	56.2	38.5	72.2
11.	VEmax (l/min)	138.15±25.18	139.0	106.9	203.6
12.	VO_{2AT}/ VO_2max (%)	54.1±6.9	56.2	40.7	66.3
13.	VO_2max/W (ml/min/kg/W)	13.42±2.51	12.95	9.03	18.13

We attempted to evaluate the relationships between the main parameters of CPET at rest, at anaerobic threshold and at the peak of exercise. There were no statistically significant correlations between oxygen consumption, heart rate and pulmonary ventilation at rest for the basketball players. Statistically significant correlations occurred between all the main parameters of CPET at anaerobic threshold. We also found a significant correlation at the peak of exercise between maximal oxygen consumption and minute ventilation. Also we detected correlation at the peak exercise between minute ventilation and heart rate. We found a correlation between heart rate and oxygen consumption at the peak exercise as well. Figures 1–3 illustrate the established relationships between the main parameters of CPET at anaerobic threshold and at the peak of exercise.

As shown in Figure 1, there are statistically significant correlations between oxygen consumption and heart rate at anaerobic threshold. This significance disappears at the peak of exercise.

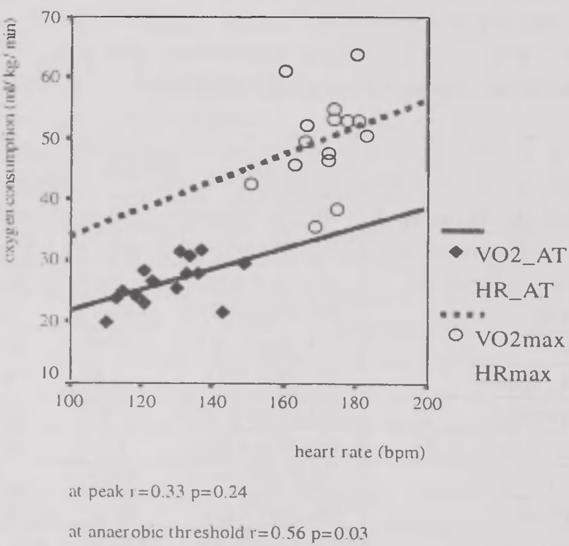

Figure 1. Relationships between heart rate and oxygen consumption during CPET.

Figure 2 shows clear evidence of a significant correlation between power and oxygen consumption at anaerobic threshold, but the significance disappears at the peak of exercise as in Figure 1. The relationships of VO_{2AT}/HR_{AT} and VO_{2AT}/P_{AT} are characterised by very similar correlation coefficients as is seen in Figures 1 and 2.

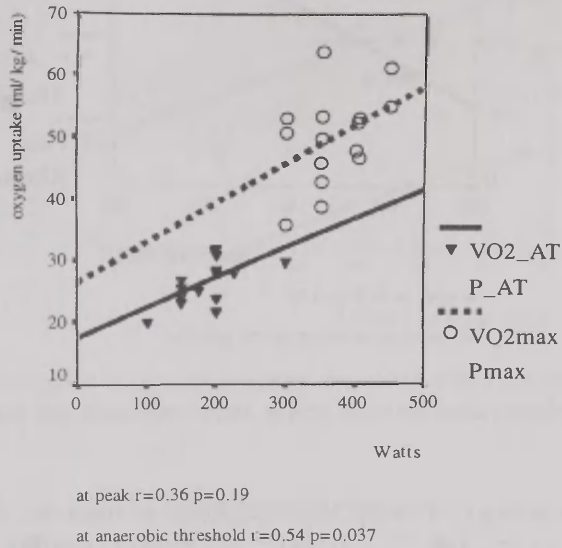

Figure 2. Relationships between power output and oxygen consumption during CPET.

Figure 3 demonstrates that the correlation between power and heart rate at anaerobic threshold was more pronounced than the correlation between oxygen uptake and power. A negative correlation at the peak of exercise between heart rate and power is not statistically significant.

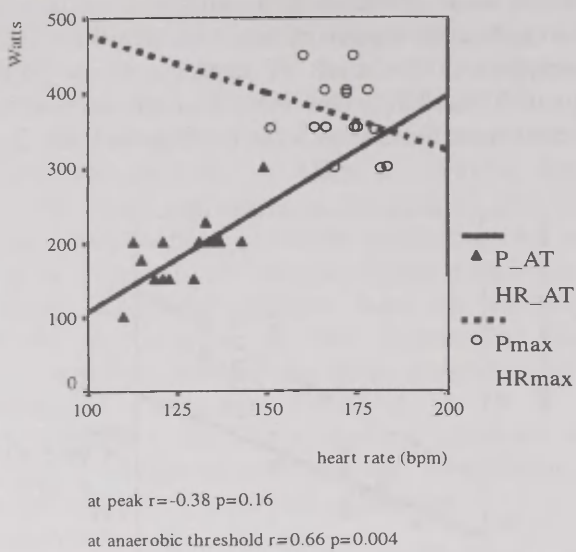

Figure 3. Relationships between power output and heart rate during CPET

We found a strong correlation between power at anaerobic threshold at the peak of testing (r=0.77, p=0.0007). We failed to confirm correlation between VO_{2AT} and VO_{2max} (r=0.48, p=0.07), or between HR_{AT} and HR_{max} (r=0.11, p=0.7), or between VE_{AT} and VE_{max} (r=0.09, p=0.74) during CPET for the studied basketball players.

Relative power was calculated for the Pmax/body mass ratio. We confirmed strong correlations between relative power and oxygen consumption at anaerobic threshold (r=0.595, p=0.019) and at the peak of exercise (r=0.638, p=0.01). Thus an athlete in a better aerobic condition can attain higher relative power. This relationship is expressed indirectly in Figure 4 by the scatterogram VO_{2AT} versus VO_{2max}. The cases are labeled by relative power. In general, this graph shows that the points of higher relative power are located in the upper right corner, which represents better aerobic condition.

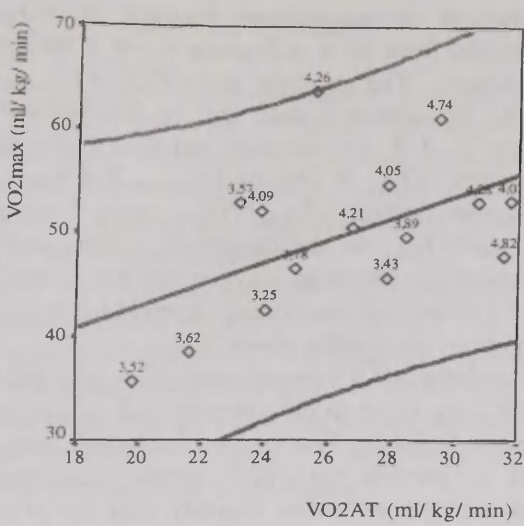

Figure 4. Scatterplot of oxygen consumption labeled by relative power.

DISCUSSION

There are no well-established or widely accepted standardized testing profiles for basketball players [7]. The development of standardized laboratory measurements of exercise capacity reflects the growing recognition of the importance of these investigations. The purpose of this study was to quantify the aerobic capacity of professional basketball players during CPET. A number of previous studies have described physiological tests for high level basketball players [12,13]. However, in these studies, the information based on the results or normative values for male basketball players during CPET is insufficient.

Mean maximum oxygen consumption was 49.83 ml/kg/min, with a maximum value of 63.8 ml/kg/min and a minimum of 35.6 ml/kg/min, which are similar to those found by Malicevic et al. in European basketball champions of the year 2001 [9]. Hoffman [7] reported VO_{2max} ranging from 42 to 59 ml/kg/min in basketball players. Laplaud et al. [8] showed an insignificant increase in VO_{2max} in French basketball players from 41.8 ml/kg/min to 44.1 ml/kg/min during a competition season. The average ratio VO_{2AT}/VO_{2max} is 54% and corresponds to Wasserman's data and to the normative values for healthy persons [1, 2, 5, 15]. Scheller and Rask [12] supposed that for basketball players VO_{2AT} is 75% of VO_{2max}. We found no basketball players displaying a similar VO_{2AT}/VO_{2max} ratio. The highest value for the ratio VO_{2AT}/VO_{2max} for the basketball players studied by us was 66%. We confirmed increased oxygen uptake at rest. This finding agrees with the standpoint that energy expenditure at rest for athletes is higher than average for healthy adults [16].

We can conclude that the mean values of oxygen uptake in different stages of CPET are close to the upper bound of normative values for healthy persons [1,5,15]. The studied basketball players cannot be characterised as persons with high aerobic performance. Hoffman suggests that increase in aerobic capacity does not provide additional advantage in basketball [7]. In our previous study, we showed that recovery after CPET in the same study participants was not optimal [6]. Obviously, good aerobic conditioning serves as a basis for qualitative recovery after maximal efforts during games and practices.

Despite the fact that we did not find reference values regarding VE_{max} of basketball players for comparison, we can state that VE_{max} is not an exercise limiting factor [1,2,5].

The level of aerobic performance of the participants is characterised by the heart rate values attained during CPET. HR_{AT} average during CPET was 124 bpm, or 74.6% from HR_{max}. Evidently such HR_{AT} values are determined by specific CPET.

Roecker et al. [11] demonstrated that HR_{AT} was lower during veloergometry than when a treadmill was used for exercise testing; however, heart rate at the peak of the exercises was more similar. Although cycling is not usual activity for basketball players, it allows measurement of direct power output. The mean and median values of power output in our study sample are higher than the corresponding values reported in other studies [8,10]. Higher relative power is associated with better aerobic performance. VO_{2max} is related to the position of the players on the field [7].

CONCLUSIONS

We found statistically significant correlations between all the main parameters of CPET at anaerobic threshold. We suggest that disappearance of statistically significant correlations between heart rate, oxygen uptake and power output at the peak of exercise could be associated with the nonlinearity of responses during final or maximal stage of testing between these variables.

On the basis of these data we conclude that incremental CPET gives reliable information about the aerobic performance of basketball players and provides important information for determination of exercise loading. Also, the data could provide a source of reference for this field of sport and might be useful for monitoring and evaluating present and future players.

The collected data allows to study the dependence of intensity of specific basketball exercise from aerobic capacity.

REFERENCES

1. ACSM's Guidelines for Exercise Testing and Prescription. (2000) 6th edition. Lippincot, Williams & Wilkins, Philadelphia
2. American Thoracic Society & American College of Chest Physicians (ATS/ACCP) (2003) Statement on cardiopulmonary exercise testing. Am. J. Respir. Crit. Care Med. 167: 211–277
3. Bassett D., Howley E. T. (2000) Limiting factors for maximum oxygen uptake and determinants of endurance performance. Med. Sci. Sports Exerc. 32: 70–84
4. Crisafulli A., Melis F., Tocco F., Laconi P., Lai C., Concu A. (2002) External mechanical work versus oxidative energy consumption ratio during a basketball field test. J. Sports Med. Phys. Fitness. 42: 409–417
5. Fletcher G. F., Balady G. J., Amsterdam E. A., Chaitman B., Eckel R., Fleg J., Froelicher V. F., Leon A. S., Pina I. L., Rodney R., Simons-Morton D. A., Williams M. A., Bazzarre T. (2001) Exercise standards for testing and training: a statement for healthcare professionals from the American Heart Association. Circulation 104: 1694–1740
6. Gocentas A, Andziulis A. (2004) Changes in oxygen consumption of basketball players during recovery after maximal load. Medicina (Kaunas). 40: 569–573

7. Hoffman J. R. (2003) Physiology of basketball. In: McKeag (ed.): Basketball. Blackwell Science, 12–24
8. Laplaud D., Hug F., Menier R. (2004) Training-induced changes in aerobic aptitudes of professional basketball players. Int. J. Sports Med. 25: 103–108
9. Malicevic S., Mazic S., Igracki I., Nesic D. (2002) Comparative analysis of ergometric parameters of European basketball championships 2001 winners — cadets vs. seniors. Abstract book of XXVII FIMS World Congress of Sports Medicine. Budapest, Hungary. 2002: 38
10. McInnes S. E., Carlson J. S., Jones C. J., McKenna M. J. (1995) The physiological load imposed on basketball players during competition. J. Sports Sci. 13: 387–397
11. Roecker K., Striegel H., Dickhuth H. H. (2003) Heart-rate recommendations: transfer between running and cycling exercise? Int. J. Sports Med. 24: 173–178
12. Scheller A., Rask B. (1993) A protocol for the health and fitness assessment of NBA players. Clin. Sports Med. 12: 193–205
13. Stapff A. (2000) Protocols for the physiological assessment of basketball players. In: Gore CP (ed.): Physiological tests for elite athletes. Australian Sports Commission. Human Kinetics, Champaign. 224–237
14. Tomlin D. L., Wenger H. A. (2001) The relationship between aerobic fitness and recovery from high intensity intermittent exercise. Sports Med. 31: 1–11
15. Wasserman K., Hansen J. E., Sue D. Y., Casaburi R., Whipp B. J. (1999) Principles of exercise testing and interpretation. 3rd edition. Lippincott, Williams & Wilkins. Philadelphia
16. Westerterp K. R. (2001) Limits to sustainable human metabolic rate. J. Exp. Biol. 204: 3183–3187

Correspondence to:
Anatoli Landõr
Department of Sports Medicine and Rehabilitation
University of Tartu
Puusepa 1a
Tartu 50406
Estonia

MOTOR PERFORMANCE IN MENTALLY RETARDED 14–15-YEAR OLDS USING UNIFITTEST (6–60) BATTERY

P. Tilinger, A. Lejčarová
Faculty of Physical Education and Sport, Charles University, Prague, Czech Republic

ABSTRACT

The aim of this study was to find out the level of basic motor performance in 14–15-year old retarded pupils in Prague. In total, 175 pupils (137 boys and 38 girls) were studies using Unifittest (6–60) battery.

Mentally retarded pupils of special schools show, on the whole, in comparison with the standards of the Czech population, performance below average to significantly below average; the only exception is the average performance of boys in tests "Shuttle run 4x10 m" and "Pull-ups". The results confirm the necessity to deal with this serious problem and to look for the resources how to increase the level of motor performances in pupils of special schools both in school physical education and out-of-school physical activities and sport

Keywords: motor performance, special schools, mental retardation, Unifittest

INTRODUCTION

There is a quite specific group of disabled individuals with mental retardation (MR) in a number estimated at 2 to 3 % in the population. Individuals with mild MR (approaching 80%) belong to the most frequent in this group. They attend special schools where they receive their compulsory education. Motor and working skills belong to the conditions that could help them to a successful realization of the future working process aimed especially at manual activities. The level of an optimal physical fitness should be regarded as crucial for acquiring the working skills and those capacities may be decidedly influenced in school physical education lessons in those children.

In the Czech Republic, considerable attention was paid to the testing and evaluation of the motor capacities and physical fitness of normal population; however, in mentally retarded children and youth, those procedures are not investigated as often as would be desirable. It is therefore important to obtain the basic information on the level of physical fitness and motor skills in pupils with MR and on the basis of that to develop fundamentals for conceptions of adequate programmes of physical education processing and its improvements at special schools [1,2,3, etc.]

The main purpose of the study was to ascertain the level of basic motor performances of the pupils of the so-called older school age at special schools in selected motor tests and to compare the obtained results with the normal population of the same age.

METHODS

The pupils of all special schools in Prague (for individuals with mild MR) aged 14–15 years were selected. Some of the pupils could not be tested by the whole battery of tests from some health limitations (epilepsy, heart disease, asthma), and so these pupils were not enrolled in the individual items of the final elaboration of results. In total, 175 pupils were tested, 137 boys and 38 girls.

For the evaluation of motor performances, the test battery UNIFITTEST (6–60) was used. Motor tests that require minimum demands on the level of motor skills are in our view suitable for application at special schools. The following tests were regarded as a common basis: "Standing broad jump", "Sit-ups", "12 minute run". The fourth test was elective: for boys and girls aged 14 years "The shuttle run" was assigned, the test "Pull-ups" was selected for 15-year old boys and "Flexed arm hang" for girls of the same age.

All of the motor tests were carried out unrepeated in one day during two lessons of physical education. The demands on time depended on the number of individuals in the group: mostly in the first lesson and partly also in the second lesson the first tests were realized in a gymnasium in a sequence "Standing broad jump"–"Sit-ups"–"Shuttle-run"–"Pull-ups"/"Flexed arm hang", and in the remaining time of the second lesson, the "12 minute run" took place. In case the order of the tests could not be preserved, the condition was always fulfilled so that in every sequence the tests with predominant endurance loads ("Sit-ups" and "12 minute run") were carried out as last from evident reason of possible distortion of results owing to fatigue. The information about the individual tests and the purpose of the procedures were always explained to the pupils. They also obtained precise instructions for the execution of individual tests, which was connected with demonstrations. Practice trials were allowed. A warm-up was employed before the testing, supervised by the physical education teacher or one of the tested pupils.

For the individual assessment and comparison of results within the range of the population group of the given sex and age, the norms were used according to the "Manual for assessment of the level of basic motor performance and selected somatic characteristics of school children and youth aged 6 to 20 years" [4]. Those norms are ten grades norms and they allow to make assessments quantitatively (in ten points scale 1–10), as well as qualitatively. They have the following categories: significantly below average (1–2 points), below average (3–4 points), average (5–6 points), above average (7–8 points), significantly above average (9–10 points). The arithmetic mean of the norm corresponds to 5.5 points when no performance can be assessed by zero point.

RESULTS AND DISCUSSION

Table 1. Descriptive statistics of performances of pupils at special schools in motor tests compared with norms

Tests	Boys 14 ys	Girls 14 ys	Boys 15 ys	Girls 15 ys
Standing broad jump (cm) – N	44	15	93	22
– Mean x	177.3	136.8	180.6	147.2
– Standard deviation s	26.19	23.02	30.20	23.82
– Variation range R	142	76	154	89
– x_{max}	238	169	245	182
– x_{min}	96	93	91	93
– Norm	185–208	167–187	200–222	170–190
Sit–ups recurrent /n/min/ – N	44	15	92	22
– Mean x	35.3	28.9	36.4	26.9
– Standard deviation s	9.3	6.5	8.1	8.8
– Variation range R	41	23	40	36
– x_{max}	54	41	50	37
– x_{min}	13	18	10	1
– Norm	36–44	31–39	39–47	32–41
12 minute run /m/ – N	42	14	87	19
– Mean x	1779	1673	1726	1662
– Standard deviation s	498.2	376.5	557.8	437.9
– Variation range R	1860	1310	2750	1770
– x_{max}	2800	2600	3000	2530
– x_{min}	940	1290	250	760
– Norm	2271–2650	1953–2307	2329–2711	1941–2280
Shuttle run 4x10 metres /s/ – N	44	16		
– Mean x	11.9	13.4		
– Standard deviation s	0.87	1.22		
– Variation range R	3.4	4.8		
– x_{max}	13.9	16.4		
– x_{min}	10.5	11.6		
– Norm	12.6–11.2	12.9–11.5		

Tests	Boys 14 ys	Girls 14 ys	Boys 15 ys	Girls 15 ys
Pull-ups (n) / Flexed arm hang (s) – N			92	22
– Mean x			3.03	4.41
– Standard deviation s			2.75	4.74
– Variation range R			10	17
– x_{max}			10	17
– x_{min}			0	0
– Norm			3–6	6–14

Testing results are presented in Table 1.

Test 1 "Standing broad jump"

The majority of girls attained significantly below average performance, below average, in lower number average performance (1–6 points). On the whole, 54% of girls and 39% of 15-year old boys attained a performance significantly below average (1–2 points) as compared to one quarter of 14-year old boys. 38% of 15-year old boys and 34% of 14-year old boys attained a performance below average (3–4 points). When comparing the total mean performance with the standards for the Czech population, it is possible to conclude that girls at special schools had performances significantly below average in both categories (2 points), the sample of boys in both age categories below average performance when the total mean performance in 14-year old boys corresponded to 4 points and 15-year old to 3 points. More than 26% of pupils accomplished the norms.

Test 2 "Sit-ups"

In this test, 73% of girls and 76% of boys appeared in the zone of below average and average performance, which was nearly the same. On the whole, in comparison with the standards of the Czech population, it was possible to record that our sample of girls demonstrated performance below average in both age categories corresponding to 4 points in 14-year old and 3 points in 15-year old girls. The boys were classified as belonging to below average performance in both categories (4 points). Approximately 45% of the pupils accomplished the norms.

Test 3 "12 minute run"

On the whole, 55% of the girls attained significantly below average performance. Also, in boys, the assessment in points fluctuated from low to very low assessments. This was more varied in the category of 14-year old pupils, where 57% of boys obtained only 1 point and in case of 15-year olds, 51% attained that assessment from the whole number of tested pupils.

Compared with the standards of the Czech population, the sample of girls attained below average performance /3 points/ in both age categories, the sample of boys the same performance was classified by 2 points in 14 years old boys and by 1 point in 15 years. Performance in endurance running was at a very low level–only 18% of pupils accomplished the norms.

Test 4 "Shuttle run 4 times 10 meters"

The majority of girls (81%) attained average and below average performance (3 to 6 points); in boys, the distribution of point assessments was around the mean values. On the whole, 59% of the boys were able to reach average performance (5–6 points). It was interesting that none of the followed pupils was classified by a performance significantly below average (1–2 points), which was the case the first time in the investigation.

The total mean performance attained by girls in that test belonged to the zone below average (4 points), unlike the standard of the population, the boys demonstrated similar performances as the population in the Czech Republic (as average — 5 points). The speed capacities seemed to be at a good level — 70% of pupils accomplished the norms.

Test 5 "Pull-ups"/"Flexed arm hang"

The majority of girls attained significantly below average, below average or average performances when 36% from the number of tested girls demonstrated significant below average performance (that means being not able to hold a pull — 1 point). 40% of boys had average performances in that test and, on the other hand, 27% of boys attained performances significant below average (which was assessed by 1 point — no pull-up).

In comparison with the standards for the Czech population, the total mean performance of girls belonged to the zone below average (4 points), whereas the sample of boys from special schools attained a similar performance as the population in the Czech Republic — average (it is 5 points). On the whole, about 48% of pupils accomplished the norms.

CONCLUSIONS

The results suggest that the pupils from special schools show, on the whole, a performance below average when compared to the standards of the Czech population; in the test "Standing broad jump" in girls and in the test "12 minute run" in boys, performances appear to be even significantly below average. There are only two exceptions: boys aged 14 years in the test "Shuttle run 4 times 10 meters" and 15-year old boys in the test "Pull-ups" — both groups attained performances equal to population standards — average performance.

Investigation revealed that pupils attending special schools dispose of very low level of their motor performances and of physical fitness [5,6,7,8,9]. There is, however, no doubt that individuals with MR possess — in the range of their deficiencies, sufficient competences as prerequisites for the development of motor abilities and acquirement of skills. Nevertheless, the majority of the pupils of special schools are passive in the out-of-school voluntary sport activities and they join in motor activities only during compulsory physical education — therefore, for that reason, great attention must be paid to compulsory physical education lessons as well as due to space for those lessons.

References

1. Eichstaedt C. B., Lavay B. W. (1992) Physical activity for individuals with mental retardation. Champaign, IL: Human Kinetics
2. Fernhall B. (1993) Physical fitness and exercise training of individuals with mental retardation. Med. Sci. Sports Exerc. 25: 442–450

3. Horvat M., Franklin C. (2001) The effects of the environment on physical activity patterns of children with mental retardation. Res. Q Exerc. Sport. 72: 189–195
4. Kovář R., Měkota K., Chytráčková J., Kohoutek M., Gajda V., Moravec R. (1993) Manuál pro hodnocení úrovně základní motorické výkonnosti a vybraných charakteristik tělesné stavby školních dětí a mládeže ve věku od 6 do 20 roků. *Těl. vých. mlád.* 59: 3–63
5. Draheim C. C., Williams D. P., McCubbin J. A. (2003) Cardiovascular disease risk factor differences between Special Olympians and Non-Special Olympians. Adapted Phys. Act. Quart. 20: 118–133
6. Dupped M. A. (1990) Effects of a 10-week aerobic exercise program on the physiological, cognitive and behavioral functioning of institutionalized retarded children. In Vermeer A. (ed.). Motor development, adapted physical activity and mental retardation. Basel : Karger
7. Kioumourtzoglou E., Batsiou S., Theodorakis Y. (1995) Age difference and physical fitness levels of mentally retarded and nonretarded individuals. Int. J Phys. Educ. 32: 24–28
8. Pitetti K. H., Yarmer D. A., Fernhall B. (2001) Cardiovascular fitness and body composition of youth with and without mental retardation. Adapted Phys. Act. Quart. 18: 127–141
9. Rarick G., Widdop J. H., Broadhead G. D. (1970) The physical fitness and motor performance of educable mentally retarded children. Exceptional Child 40: 509–519

Correspondence to:
Pavel Tilinger,
UK FTVS
J. Martiho 31
162 52 Praha 6
Czech Republic

INSTRUCTION TO AUTHORS

Acta kinesiologiae Universitatis Tartuensis is a multidisciplinary (publishing papers on diverse subjects from sports and exercise sciences) annual publication.

Manuscripts are accepted for consideration with the understanding that their contents have not been published elsewhere. Manuscripts are read through by the editor and by two reviewers in blind review process, which takes 8–10 weeks.

Manuscripts are to be submitted in English. Submit three clear copies of the manuscript to the editor. Maximum volume of text is 10 pages, maximum total volume is 15 pages. Type the manuscript double-spaced on one side of A4 paper with margin of 3 cm on the left side.

The manuscript should be arranged as following

1. Title page

Title of the article in capital letters, names of authors, authors institution, name and address of the principal author, up to 5 key words. For blind review, a second title page is needed that contains only the title.

2. Abstract (up to 200 words, separate sheets).

3. Text

The text should contain the following sections: Introduction, Materials and Methods, Results, Discussion, References, Acknowledgements if any. Tables and Figures should be presented on separate sheets. Figures should be professional in appearance and have clean, crisp lines. Identify each Figure by marking lightly on the back, indicating, Figure number, top side and abbreviated title of manuscript. Legends for the Figures should be submitted on a separate sheet. Tables should be double-spaced on separate sheets and include a brief title. The SI units should be used in presenting results.

Each citation in the text must be noted by number in parenthesis and must appear in the reference list as well. Each entry in the reference list must be double-spaced, arranged alphabetically and numbered serially by author with only one reference per number. Non-english papers should be cited in the original language.

Entries in the reference list should be as follows:

1. Sarna S., Kaprio J. (1994) Life expectancy of former elite athletes. Sports Med. 17 (3): 149–151
2. Gurpide E. (1975) Tracer methods in hormone research. Springer Verlag, New York
3. Morgan W. P., Borg G. (1976) Perception of effort in the prescription of physical activity. In: The humanistic and mental health aspects of sports, exercise, and recreation, T. Craig (ed). Chicago: Am. Med. Assoc. 256–259
4. Paoletti R. (1994) Future directions in drug treatment of atherosclerosis. 8th Int. Dresden Symp. on Lipoproteins and Atherosclerosis. Abstracts. Dresden, June 10–12, 1994, 22.

Page proofs will be sent to the author for marking of printer's errors. Ten reprints will be sent, free of charge, to the principal author.
Subscription rate: 20 USD (+postage) send to the editor.

ISSN 1406–9822