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Toivo Jürimäe
University of Tartu
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50090 Tartu
Estonia

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CONTENTS

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FITNESS SCORERS VARIABILITY OF TWO YOUNG ACTIVE MEN WITH DOWN SYNDROME DURING AN INTENSIVE TREADMILL TEST

Y. Eberhard[1], A. Favre-Juvin[2], V. Bricout[2], P. Flore[2], P. Garnier[3], M. Guinot[2], D. Van Biesen[4], P. Van de Vliet[4]

[1] Laboratoire de Bioénergétique Fondamentale et Appliquée (LBFA, UJF)
[2] Hypoxie, Physiologie, Physiopathologie,
UF de recherche Clinique sur l'exercice musculaire (CHUG & UJF)
[3] Département de Pédiatrie (CHUG & UJF)
[4] Department of Rehabilitation Sciences,
Katholieke Universiteit Leuven, Belgium
UJF = Université Joseph Fourier, Grenoble I, France
CHUG = Centre Hospitalier Universitaire de Grenoble, France

ABSTRACT

The aim of this case-study is to focus on contrasted results on fitness scorers obtained in two young active men with Down Syndrome (DS) who were engaged in an exercise protocol to investigate the effect of muscular exercise on hormonal secretions and oxidizing stress.

Both adults with DS participated in a 40 minutes progressive treadmill protocol (10' at 30% of VO_2 max. + 10' at 50% of VO_2 max + 20' at 70% of VO_2 max.), with registration of cardiac frequency, blood glycaemia, blood lactate and respiratory ventilation at the end of each stage and after the test was completed.

For the same time duration (40 minutes) of muscular exertion, and the same distance covered (2800 meters walking-running), physiological differences have been observed between these 2 active persons with DS on fitness scorers at the third stage (70% of VO_2 max): (i) cardiac frequency (149 vs 190 bpm); (ii) glycaemia (0.99 vs 1.1 g/L^{-1}; (iii) lactataemia (2.4 vs 9.6 mmol/L^{-1}); respiratory ventilation (34.4 vs 94.7 L/min^{-1}).

The present findings are an example of the between-subject variability encountered in the evaluation of the physical fitness level of persons with Down Syndrome. Here, it is showed that physical capacities can vary to double between two active male subjects with DS, capable to finish a progressive and maximal aerobic physical test. Discussion and conclusion underline the interest to promote increased physical activity participation among persons with DS in order to reduce the potential health risks associated with low fitness and sedentary behaviour.

Key words: Down syndrome, adapted physical activity, exertion; treadmill test, VO_2 max, fitness scorers, variability

INTRODUCTION

Persons with Down Syndrome (DS) hold a genetic disease well identified from Lejeune et al. [10]. The presence of an extra chromosome 21 (so-called trisomy 21) causes a multitude of major and minor abnormalities that collectively create the phenotype referred to as Down syndrome [4]. More, it is admitted [12, 13] that the triplication of the underband 21 q 22 induces a real genetic overdose which can be considered as a permanent biochemical and metabolic stress. This phenomenon induces an early and accelerated ageing process, and mainly in sedentary people with DS.

An aerobic physical exercise test, which always needs increased oxygen consumption, corresponds to a cell stress in vivo, with accompanying variations, adaptations or regulations between all physiological systems in the body. The fundamental paradigm pursued [3] is to know whether the energetic pole of physical exercise is able to strongly modify, at least in transitory manner, the "genetically determined" pole.

What happens after a bout of physical exercise in the genetic overdose of enzyme production at the level of the underband 21 q 22.1 in, for example, (among a list of ten enzymes coded on the chromosome 21): 1) the SOD-1 enzyme, which protects all the cells of free radicals derived from oxygen metabolism? 2) the PRGS enzyme engaged in the biosynthesis of mononucleotides (Figure 1)?

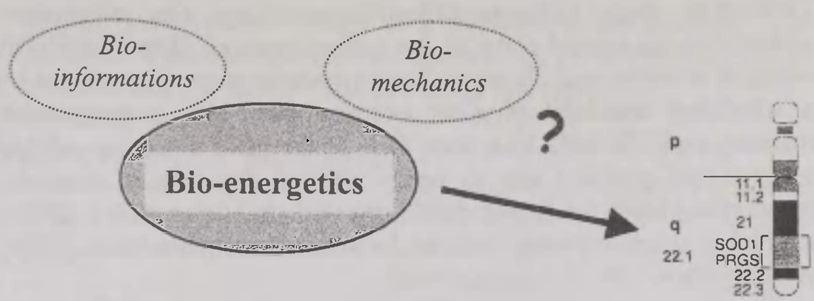


Figure 1. Example of paradigm pursued in exercise physiology adapted to persons with DS from Eberhard [3].

(SOD-1 enzyme = superoxide dismutase-1 activity in red cells, fibroblasts, platelets, lymphocytes, brain, granulocytes; PRGS enzyme = phosphoribo-glycinamide synthetase activity in fibroblasts)

Investigations in the exercise physiology domain, from the 80' on, have certainly contributed to a better understanding of the biological processes attached to the specificity induced by trisomy 21. At present, it is well known that biological and metabolic changes in the organism happen proportionally to the intensity of muscular activity. Some supposed limitations or deregulations concerning persons with DS are well described in literature. Those include: poor physical capacities and difficulties to improve fitness [11], subactivity in hormonal secretions [7, 9], and attenuated responses to sympatho-excitation in individuals with DS [5].

Furthermore, physical exercise tests suppose, along with biological and metabolical variations, task understanding. This cognitive part is linked to the quality of the movement production, even though the series of movements is simple or as natural as walking, and to a volitional side, which is to go to the maximum of the neuro-motor capacities. A part of intellectual deficit in cognitive processes is always associated to trisomy 21. This leads to the following recurrent questions: do they understand…? Can they fulfil…? Will they succeed… the requirements of an exertion physical exercise protocol?

With this in mind, adults with Down syndrome (carrier of a free and homogeneous trisomy 21 and all subjects with DS presented a "moderate" level in intellectual capacities, (IQ = 35–55, in reference to IQ classification of Grossman [6]) were invited to participate in the

TREFHOR study (TRisomyEFfortHOrmonology: the information striked through should come in the method section). The TREFHOR protocol aimed to study hormonal and metabolic responses induced by a laboratory treadmill physical exercise test, with a progressive intensity until 70–80% VO_2 max. One of the main objectives of that experimental protocol was to verify whether this type of muscular stimulations leads to: 1) particular hormonal changes and 2) a further oxydizing stress in young male adults with DS compared to a control group, without DS, of same age rank.

For persons with intellectual deficits, self-evaluation of the perceived effort (e.g. the auto-quotation of Borg scale [1]) cannot be used by lack of reliability. Parameters from laboratory techniques (monitoring or metabograph analyser) can then be an indicator of changes during a continuous effort triangular test underlying an exhaustion phase: cardiac frequency at each intensity level; glycaemia evolution; air volume ventilated during the time of the test (VE); lactataemia upper 8 mmol/l; a respiratory quotient (RQ) > 1.1; a rough desaturation (lack of oxygen capitation by hemoglobin, low than 85%. Furthermore, global behaviour assessment during the test is requested (e.g. inability to support the require intensity, suffering signs).

In the present study, results of two young adults with DS that participated in the test are compared as example of the heterogeneity of the responses to exercise in this population.

MATERIALS AND METHODS

Participants

The TREFHOR investigation aims to investigate the exercise tolerance in 14 young male adults with DS (mean age of 22 years) who all successfully completed a progressive physical test of walking-running on a maximal progressive treadmill test in 40 minutes duration after a training experience in laboratory consisting in: 1/: 3 stages of 1 hour duration for a familiarization "walking-running" on treadmill before the final test and 2/: 3 stimulations by session in increasing the elevation of the treadmill.

In this investigation, results of 2 participants are reported. Characteristics of the two subjects are given in Table 1. They are named by their initials (LC and SV) further along this paper.

Table 1. Participants' characteristics

Participant with DS	Age (years)	IQ level KABC test [8]	Height (cm)	Weight (kg)	VO_2 max. (ml/kg^{-1}/min^{-1})	BMI (kg/m²)	Adipose mass (%)
LC	26	borderline with severe level	157.3	67	23.3	27.2	27.9
SV	27	moderate level	157.8	74	39.0	29.7	22.4

Protocol and measurements

LC and SV participated in a continuous maximal incremental protocol walking or running on a treadmill (Gymrol Super 2500, Andrézieux-Bouthéon, France) at a nearly constant ambient temperature (19–20°C). The protocol consisted in a modified version of the Balke protocol. After adjustment to a comfortable walking (i.e 4 km/h^{-1}), the slope was increased by 2% every 2 minutes until exhaustion. Three effort sequences were set: 10' at 30% of VO_2 max, 10' at 50% of VO_2 max, 20' at 70% of VO_2 max. Gas exchange parameters and cardiac frequency or heart rate (HR) were continuously recorded with an automatic computerized analysis system (Brainware, Toulon, France). Both pneumotachograph and gas analysers were calibrated before each test with a 3-L syringe and precision mixed gases (CO_2 and O_2). VO_2 and HR corresponding to each step and to maximal achievement were obtained by averaging the last minute of each step and the last minute before exhaustion. At the end of each step and immediately after the end of the exercise a 20 μl capillary blood sample was taken from the fingertip for glycaemia and lactic acid measurement (SGI Microzym-L, Toulouse, France).

VO_2 max is a quantitative statement of an individual's capacity for aerobic energy transfer. As such, it is one of the more important factors that determine one's ability to sustain high-intensity exercise for longer than 4 or 5 minutes. Each successive stages of 10 minutes duration at 30, 50, and 70% of VO_2 max. (by 3 elevations of the treadmill) requires a greater energy output and thus places an additional load of the walker's with DS capacity for aerobic metabolism.

At rest, blood glycaemia is known to be low in population with DS [2]. For able-bodied persons, this variable is generally stable (= 1 g/L^{-1}) on this type of exercise.

Blood lactic acid concentration increases at different levels of exercise. The threshold max occurs at a higher percentage of the walker-runner aerobic capacity and expresses the intensity of the muscular work. Not many literature is available regarding blood lactate responses to muscular exercise of persons with DS.

Respiratory ventilation increases linear with muscle oxygen consumption. In general, the ventilatory equivalent is maintained at about 20 to 25 litres of air breathed per litre of oxygen consumed.

The two subjects with DS tested have benefited of same encouragement conditions during the test: presence of the mother; laboratory staff of 4–5 technicians keeping a close watch to see that all goes well; verbal encouragements; empathical atmosphere; award after successful participation.

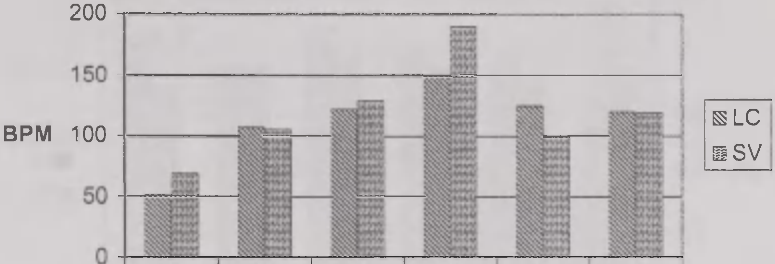
Short video sequences have been kept at the end of each intensity stages of the test. These can/must be used for the interpretation of behaviour reactions to the requirements of the test and the arrival of the muscular fatigue, inducing nervous fatigue and clumsiness in walking/running on the treadmill.

RESULTS

Considering anthropometrical data, both DS participants report a normal height and a high weight width, upper than norm. While video sequences show two behaviour attitudes that are not really very different, participant SV appears to be more concentrated on the task and finished the test in running with signs of exhaustion, whereas participant LC tends to be more jovial and more familiar with the treadmill, but he did not finish the test in running.

Both participants report a normal evolution of cardiac frequency, reaching 190 BPM for SV subject at the end of the test (vs 149 BPM for LC). (see Table 2)

Table 2. Cardiac frequency kinetics (in BPM) in two male young adults with DS, during a walking test on laboratory treadmill concluded by a last stage at 70% of their VO_2 max. during 20 minutes.



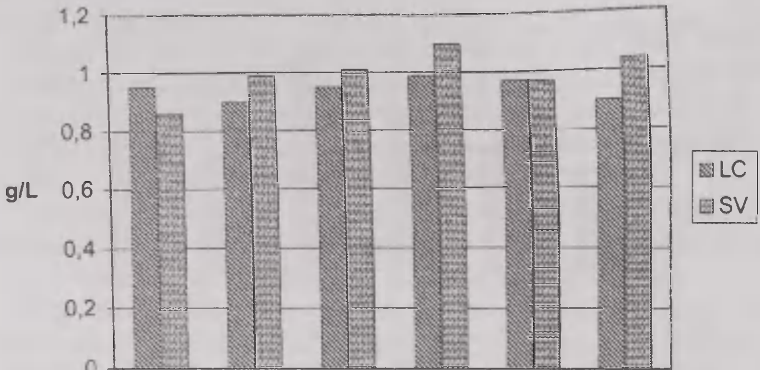
	1	2	3	4	5	6
LC	51	107	122	149	125	120
SV	69	105	129	190	99	119

Glycaemia advances normally and is identically in the two subjects with DS. There is no hypoglycaemia sign during the whole test duration as in recovery phase. (see Table 3)

With regard to blood lactate, differences between both participants can be reported. LC shows high values of lactataemia at rest, but no increase of his values with increased treadmill speed and test duration. The profile of SV on the contrary, shows a more classic rise of his lactataemia when the effort becomes longer and more intensive (see Table 4).

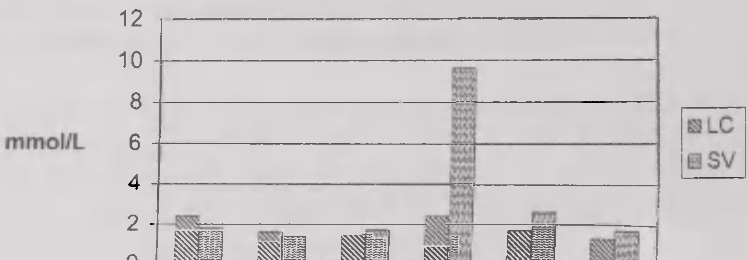
Respiratory ventilation profile (air volume kept at every stage) is strongly different at level 4 (end of stage 3: 70% of VO_2 max during 20') between the two participants. SV ventilates two times more than LC during the last stage at 70% VO_2 peak. (see Table 5)

Table 3. Glycaemia kinetics (g/L^{-1}) in two male young adults with DS, during a walking test on laboratory treadmill concluded by a last stage at 70% of their VO_2 max during 20 minutes.



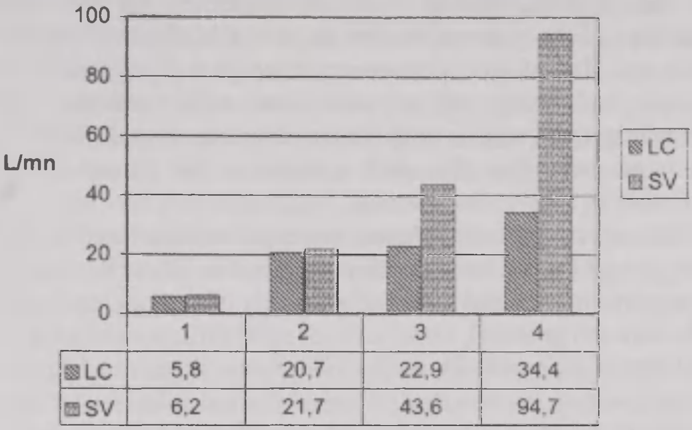
	1	2	3	4	5	6
LC	0,95	0,9	0,95	0,99	0,97	0,9
SV	0,86	0,99	1,01	1,1	0,97	1,04

Table 4. Lactataemia kinetics ($mmol/L^{-1}$) in two male young adults with DS, during a walking test on laboratory treadmill concluded by a last stage at 70% of their VO_2 max. during 20 minutes.



	1	2	3	4	5	6
LC	2,4	1,6	1,5	2,4	1,7	1,3
SV	1,8	1,4	1,7	9,6	2,6	1,7

Table 5. Respiratory ventilation kinetics (L/min^{-1}) in two male young adults with DS, during a walking test on laboratory treadmill concluded by a last stage at 70% of their VO_2 max. during 20 minutes.



For the same effort total duration and for the same treadmill flat speed, SV ventilates two times more (94.8 L/min^{-1} vs 34.4 L/min^{-1}) than LC. The physical exercise test is more exhausting for SV than for LC, which can be seen in the differences in lactataemia levels at the end of the test, (9.6 vs 2.4 mmol/L^{-1}).(see Table 6)

Table 6. Comparison of profiles between 2 participants with DS: similarities and differences concerning 7 parameters, during a continuous physical exercise test progressively at 70% of their VO_2 max.

Para-meters	Effort duration at 70% VO_2 max	Speed	Slope	Flat speed	VO_2 target	Ventilation (VE)	Distance
Units →	minutes	Km/h^{-1}	%	Km/h^{-1}	L/min^{-1}	L/min^{-1}	m
LC	20	5	4.5	8	1.1	34.4	2720
SV	20	5	4	7.6	2.02	94.8	2971

DISCUSSION

At present physical activity is promoted for everybody and at all ages. But that physical activity must be adapted to the real nature and capacities of the persons, holder or not of biological specificities or handicaps. But, when it is necessary to adapt that physical activity, for example to young adults with intellectual deficits and more particularly with persons with trisomy 21, it is not possible to use with the same reliability the self quotations for perceived effort as applicable in able-bodied persons.

The objective of the present contribution has been to show that when two young adults with DS with an active life style and compared in experimental conditions of effort (same laboratory, same materials, same duration protocol, same level of stimulations combined by speed and slope of the treadmill, etc.). Under these conditions interindividual differences can be observed in physiological adaptations varying to double. These can suggest physical capacities (*i.e* VO_2 target) varying again to double.

The results of the 2 cases presented in the present paper, put in evidence real capacities of progresses in active persons with DS who were able to sustain a test at 70% of their VO_2 max during 20 minutes with a recovery period which was absolutely normal. At the time of Lejeune's investigation [10], nobody would have opposed individuals with DS to an exercise effort at 70% of VO_2 max. However, with the current knowledge, this exercise intensity set in the present investigation, is recommended to improve cardiorespiratory "health", and the adaptations of DS individuals to this exercise intensity are normal and certainly without any danger.

Passed and present studies again show a great variability in the cognitive attainments of children with DS [14]. It was unknown to what extend this was true for physical or motor capacities. The present case-study with focus on fitness scorers puts in evidence that there is a strong heterogeousness, at least on two parameters.

On the one hand, if the SV subject ventilates two times more (94.8 L/min^{-1} vs 34.4) than LC subject, the physical exercise test of SV is certainly more improved, which is confirmed by a VO_2 target varying to double (2.02 L/min^{-1} vs 1.1).

On the other hand, if lactataemia scorer is a reflect of anaerobiosis glycolysis and traditionally admitted as a witness of motivation or volition to go further the more as possible SV is better than LC on psycho-physiological aspect accompanying an exertion situation. The comparison between SV subject and LC subject for lactataemia level at stage 4 (70% of VO_2 max) was 9.6 mmol/l^{-1} vs 2.4. SV subject was able, with a greater volition, to dip into his glycogen reserves, which was accorded with the subjective observation of the video sequences. He ended the test in running during the last minute, in spite of the arrival of fatigue and suffering signs.

At first, not many references are available that report lactataemia levels in persons with DS in different situations of training or performance, and it is difficult to argue more from only two experimentations on subjects with DS.

But also other argumentation can explain the stronger participation or adhesion in the exercise protocol of SV. Considering the IQ level, SV is classed with a “moderate” intellectual deficit whereas LC is in the more “severe” category. SV was supposed to have a better understanding of the task and to have a better attitude mainly at stage 4 (70% of VO_2 max.) of the trial. The latter is confirmed by the video behaviour study at the end of stage 4: SV subject was able to end the protocol in running during the last minute, LC not.

Among our two subjects with DS one (SV) is better than the other for muscular exercise production. We can assert that the behaviour difference pointed at, in that condition of muscular exertion, is more at a cognitive level than at a peripheral level, for example possible metabolism impairments for the muscular outpout of the weakest (LC). For LC vs SV, BMI is lower and adipose mass higher. It is well admitted that they are indicators of a previous sedentary life style.

CONCLUSION

In conclusion to the initial question in the introduction, “who is the best one?” in two young active men with DS who were able to complete a maximal progressive treadmill test, the answer is that SV is better due to a better understanding and a better management of the task and certainly due to a more active life style giving him a better body composition.

Hence, it seems that effort must be continued to promote increases in physical activity participation among persons with DS, not limited to physically active youngsters with DS, in order to reduce the potential health risks associated with low fitness and sedentary behaviour.

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Correspondence to:
Yves Eberhard
Université Joseph Fourier, UFRAPS
BP 53
38041 Grenoble Cedex
France

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O_2 UPTAKE, MUSCLE LACTATE PRODUCTION AND PHOSPHOCREATINE BREAKDOWN DURING A GIANT SLALOM RACE

P. Gramvik[1], R. Aaserud[1], S. Liavaag[2], J. I. Medbø[3]

[1]Agder University College, Faculty of Health and Sports, Kristiansand, Norway

[2]Aust-Agder Central Hospital, Arendal, Norway

[3]National Institute of Occupational Health, Oslo, Norway

ABSTRACT

To quantify the anaerobic and aerobic energy release during a giant slalom race, eight male top junior alpine skiers with a maximal leg strength of 1.87 ± 0.10 kg kg^{-1} body mass (mean ± SEM of a full squat) carried out a giant slalom race lasting 70.1 ± 0.4 s in a track fitting the World Cup standards. Muscle biopsies, taken from the knee extensor muscle at rest and immediately after the race, were analyzed for the concentrations of lactate and phosphocreatine. The O_2 uptake was measured continuously during the race by a portable metabolic analyzer. The muscle lactate concentration rose by 11 ± 1 mmol kg^{-1} wet muscle mass, while the phosphocreatine concentration fell by 8 ± 1 mmol kg^{-1} during the race. The total anaerobic ATP-production was consequently 25 ± 3 mmol kg^{-1} muscle. The O_2 uptake rose during the race to a peak of 48 ± 2 ml/min^{-1} kg^{-1} body mass at the end (83% of the maximal O_2 uptake). The accumulated O_2 uptake was 44 ± 2 ml kg^{-1} body mass. The relative contribution from anaerobic and aerobic processes to the total energy release was 33 and 67%, respectively. The race time and the total energy release both correlated negatively with the leg muscle strength. Neither the anaerobic nor the aerobic energy release seemed to be taxed maximally during a giant slalom race. The strongest skiers were in addition the fastest.

Key words: Giant slalom, oxygen uptake, lactate, phosphocreatine, muscle; Na(+)-K(+)-Exchanging ATPase.

INTRODUCTION

A giant slalom skiing race lasts 60–80 s, and giant slalom has been characterized as the most technically, tactically and physically demanding discipline in alpine skiing [12]. For instanse running and bicycling leading to exhaustion in the same duration, aerobic and anaerobic processes contribute about equally to the energy release [19–21, 30]. Moreover, for anaerobically trained subjects the rate of energy release will be above 150% of that corresponding to the maximal O_2 uptake [19]. For exercise at lower intensity and thus not being exhausting within the same time frame, the anaerobic contribution is less [16]. When exhaustion is reached in the studies mentioned above, the subjects appear poorly coordinated, being barely able to walk for the first seconds after the exercise. This state is quite different from that of alpine skiers just after a race. Data from laboratory studies on bicycling or treadmill running may therefore perhaps not be extrapolated to alpine skiing.

Giant slalom is dominated by slow, eccentric muscle actions where the skiers seem to use ≈100% of their maximal voluntary force in each turn as judged from the measured EMG [3, 4]. In line with this the knee extensors of top alpine skiers may be particularly strong in eccentric movements [1]. It is thus conceivable that strong skiers perform better than weaker ones. Moreover, too much or too little force applied results in loss of time. The skier's sensitivity to the snow's surface is therefore essential for applying the optimal force in each turn, meaning that during the course a proper muscle control is essential for the performance. Fatigue, for example due to lactic acidosis, probably reduces the fine control of the active muscles. These considerations also suggest that it is not likely that a skier during a giant slalom race becomes nearly as exhausted as for the laboratory studies mentioned above. Two studies from the 1980s proposed on the other hand that the rate of energy release during a giant slalom race is 160% of that corresponding to the maximal O_2 uptake for a race lasting 70 s [28] or 120% of the maximal O_2 uptake for a race lasting

82 s [25]. These studies suggest that during the race there is a large anaerobic energy release amounting to more than 50% of the total energy release.

Several former studies carried out about 20 yr ago have examined the energy release during a giant slalom race [9, 25, 27, 28]. None of these studies measured the O_2 uptake during the whole race or got a measure of the aerobic energy release that is adequate after present standards. In several of the studies the blood lactate concentration and the O_2 debt are the only parameters of the anaerobic energy release. It is now known that neither the O_2 debt [20] nor the blood lactate concentration [16, 22] are good measures of the anaerobic energy release. Moreover, the studies of alpine skiing mentioned above did not use a course fitted for the present World Cup standards. Further studies using modern techniques and tracks are needed. We have therefore quantified the anaerobic and aerobic energy release during a giant slalom test race during conditions closely mimicking those of modern elite alpine skiing. We have finally correlated the performance and the energy release to the subjects' maximal leg muscle strength. Our main hypothesis is that the anaerobic energy during a giant slalom race is considerably less than that found during intense bicycling of the same duration.

METHODS

Subjects

Eight healthy male students at the Hovden highschool, Setesdal, Norway, served as subjects in this study. This highschool has a specific program for young, talented alpine skiers. Six of the subjects were Norwegian, one was from Finland while the last one was from Iceland. The subjects were 18 ± 1 yr old (mean ± SD), weighed 76 ± 4 kg, and were 1.81 ± 0.05 m tall. Their maximal O_2 uptake was 58 ± 2 ml kg^{-1} min^{-1} (43 ± 2 µmol kg^{-1} s^{-1}). The subjects' FIS-score (FIS = International Skiing Federation) taken as the mean of the two best results during the season in question was 66 ± 19 points. All of the skiers were among the very best junior alpine skiers, one became world champion as a junior, and another one being a national champion.

The physician in charge examined all of the subjects before they were included in the experiments. They were informed both orally and in writing about the experiments, its practical details and in particular about the procedure of taking muscle biopsies and possible discomfort before they gave their written consent to serve as subjects. The subjects were specifically informed that they were volunteers and therefore could leave the study at any stage without giving a reason for doing so. A ninth subject dropped out of the study because he was unwilling to have muscle biopsies taken, and no data are therefore given on him. The Ethics Committee of Health Region 2 of Norway approved the experiments and the protocols used.

Procedures

The race was carried out at Vestbakken skitrack (FIS homologination number Vestbakken 4311/184/94). The track runs down the hillside of the Nås mountain, starting at 1181 m above sea level, with a total descent of 350 m and being altogether 1246 m long. The slope (tangent) of the track averages 29.5%. This is a demanding track for giant slalom with a varying and uneven terrain. The track includes a hang of 58.8% decline in the first part. Altogether the skiers passed 42 gates during the track.

The race was carried out on natural, compact snow with a temperature between –6 and –2 °C. The air temperature was –1 °C (start of the track) to +1.5 °C (end of the track) for the first skier and rose to +2 (start) and +5 °C (end) for the last skier.

The subjects were told that they should carry out the race as if it was an important competition, that is as fast as possible, and they prepared their skis and warmed up accordingly. The Metamax I (Cortex Biophysic, Leipzig, Germany) portable O_2 analyzer was mounted on the subject's back in a specifically designed backpack. The whole instrument including all the accessories used (batteries, telemetric sender, face mask with the flow transducer and the backpack) weighed 3.1 kg. The subjects wore a mask (Hans Rudolf 8940) so that all expired air passed through the Metamax' flow sensor. This instrument sucks out a tiny air sample of the expired air and analyses the fractions of CO_2 and O_2 by gas sensors in the main instrument. Since the experiments were carried out at ambient temperatures down to around 0°C, the gas samples were dried by including an 18 ml tube with $CaCl_2$ in the sampling line to the gas sensors in the main instrument. The data recorded were transmitted by telemetry from the O_2 analyzer to a receiver connected to a PC placed at the end of the track.

The O_2 analyzer collects data in 10 s intervals. The start of the race was therefore synchronized with the instrument so that each race began at the beginning of a new 10-s interval. Data on the O_2 uptake from one subject was lost because of technical problems with the O_2 sensor, but his lung ventilation was properly recorded.

Muscle biopsies were taken from the lateral portion of the right knee extensor muscle immediately after passing the finish line as follows. From the finish line the subject skied further to a 60 cm tall and 30 cm wide bench placed 25 m beyond the finish line. During the race the upper part of the normal competition suit was tied around the waist for quick removal, and while skiing from the finish line to the bench the suit was pulled down before the subject sat down on the bench, thus leaving the thigh naked. Two muscle biopsies of 15–20 mg each were taken by a thru-cut biopsy needle, 18 G, 16 mm specimen notch (product no. 451816, Bard medical system, Oslo, Norway). The needle was then opened and thereafter immediately immersed in liquid N_2, thus freezing the biopsy. The first biopsy taken was frozen ≈25 s after passing the finish line. This biopsy technique does not require local anesthesia or a separate cut in the skin and muscle fascia before the biopsy is taken. Biopsies at rest were taken in the afternoon 4–5 h after the race by a Bergström-type biopsy needle and frozen in liquid N_2.

The maximal leg strength, expressed as the 1 RM (one repetition maximum) in a full squat (that is lowering to upper surface of the thigh is horizontal in the lowest position), was obtained as part of the skiers' regular testing 3–4 mo before the experiments. One subject did not carry out this test because of back problems. The maximal O_2 uptake was measured by a Sensormedics 2900 O_2 analyzer (Sensormedics Corporation, Yorba Linda, CA, USA) during treadmill running at 5.5% inclination. This test was carried out at the test laboratory of Agder University College 3 mo after the experiments. During the test the subject ran while the treadmill speed was increased stepwise until the O_2 uptake leveled off. Each test lasted 4–5 min and was carried out after a proper warming up. Two of the subjects did not take part in this test.

Analyses, calculations, and statistics

The biopsies were analyzed for the concentrations of lactate, phosphocreatine, ATP, and glucose-6-phosphate [24] and for the concentration of proteins [31] as explained in more detail elsewhere [13]. The fraction of type 1 fibers in the muscle biopsies was determined [29], and the concentration of Na^+, K^+-pumps (EC 3.6.1.37) was measured by the ouabain binding technique [17]. The values of muscle lactate, phosphocreatine, and ATP-concentrations have been corrected for different protein concentration in the biopsies taken at rest and immediately after the exercise.

The Metamax O_2 analyzer records the O_2 uptake in 10 s intervals, and the stored values are the average of those measured in the last three 10 s periods according to the manufacturer (Ralph Henkel, personal communication). This averaging is part of the hardware and can thus not be removed by proper settings in the software. Denoting the value stored after interval i for y_i and the corresponding raw, unaveraged value for x_i, one thus has

$$y_i = (x_{i-2} + x_{i-1} + x_i) / 3 \qquad (1)$$

This means that y_i is influenced not only by x_i but also by x_{i-1} and x_{i-2}, and during transients the reported value y_i lags behind the true value x_i. We wanted the true, unaveraged values $\boldsymbol{x}$ with no lag for the O_2 uptake and respiratory parameters during the race, and we therefore solved the x_i's from (1) using standard techniques from linear algebra. That approach reduced the error introduced by the lag by at least 50%, and it appears suitable for exercises lasting up to around 1 min [14].

The accumulated O_2 uptake was taken as the measured O_2 uptake integrated over the whole race. The anaerobic ATP-production in muscle was taken as

$$\text{Anae ATP-prod} = 1.5\ \Delta c\text{La} - \Delta c\text{PCr} - \Delta c\text{ATP} \qquad (2)$$

where ΔcX is the concentration of component X after the race less the value at rest and La and PCr refers to lactate and phosphocreatine; the concentration of phosphocreatine (and ATP) fell during the race. One mole of O_2 was taken equal to 6.5 mol of ATP, as for full oxidative phosphorylation of glycogen in muscles. To be able to compare the aerobic energy release expressed relative to the body mass to the anaerobic energy release expressed relative to the muscle mass, we have assumed that the working muscle mass was 25% of the body mass and that our data on the muscle metabolites in the biopsies were representative of the whole working muscle mass.

The data are given as mean ± SEM. We used *t*-tests to test for statistical significance and Pearson's product-moment correlation coefficient to examine possible relationships between two entities.

RESULTS

The experiments were carried out in the Vestbakken ski track from the Nås mountain, a track fitting the World Cup standards of the International Skiing Federation (FIS; Figure 1). The eight top junior skiers ran down this track as fast as possible, which for the present study was carried out in 70.1 ± 0.4 s. Although the temperature rose somewhat during the experiments, the snow conditions remained fairly constant. Consequently, there was no relationship between the performance time and the start sequence ($P = 0.5$).

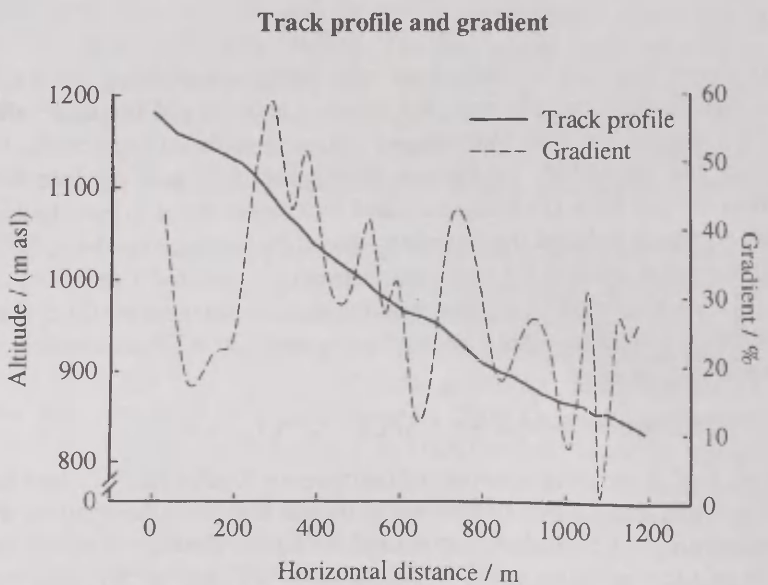


Figure 1. The track profile, taken as the altitude above the sea level (left Y-axis), and the gradient, taken as the tangent of the inclination (right Y-axis), of the track used for the giant slalom race. The X-axis gives the horizontal distance from the start.

Muscle metabolites and parameters

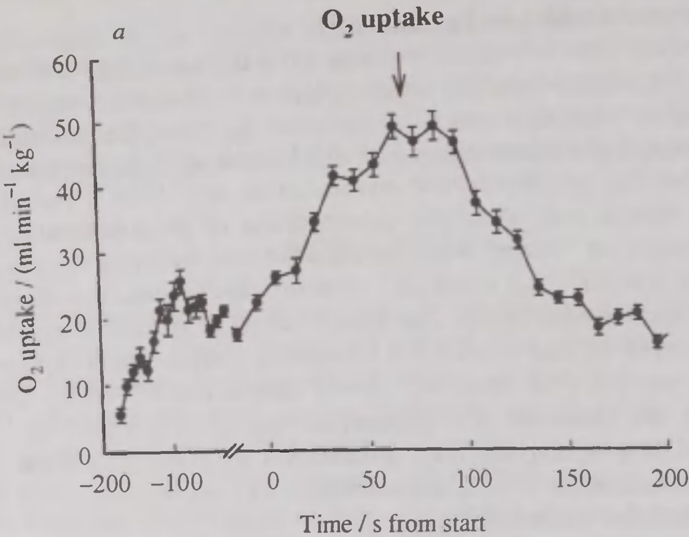
The lactate concentration at rest was 1.0 ± 0.1 mmol kg^{-1} wet muscle mass, the phosphocreatine concentration was 15.0 ± 0.8 mmol kg^{-1}, the ATP concentration was 4.2 ± 0.3 mmol kg^{-1}, and the concentration of glucose-6-phosphate was 0.13 ± 0.04 mmol kg^{-1}. In biopsies taken just after the race the lactate concentration was 11 ± 1 mmol kg^{-1} higher than at rest, while the concentration of phosphocreatine was 8 ± 1 mmol kg^{-1} lower. After the race the concentration of phosphocreatine was still 7 ± 1 mmol kg^{-1} muscle, which means that there was a considerable reserve left. The concentration of glucose-6-phosphate at the end of the race was 2.3 ± 0.4 mmol kg^{-1}, while the ATP-concentration was 0.2 ± 0.3 mmol kg^{-1} lower than at rest ($P > 0.2$). Consequently, the anaerobic ATP-production was 25 ± 3 mmol kg^{-1} wet muscle mass during the race. Breakdown of phosphocreatine (and ATP) accounted for 33% of the anaerobic ATP-production, while 67% came from the lactate production.

The Na^+-K^+ pump concentration in the knee extensor muscle was 437 ± 20 nmol kg^{-1}. The proportion of type 1 fibers in this muscle was $65 \pm 3\%$, and none of the skiers had less than 52% type 1 fibers in their knee extensor muscle.

Oxygen uptake

The O_2 uptake during the last minute before the race was 19.9 ± 0.8 ml kg^{-1} min^{-1} (14.8 ± 0.6 µmol kg^{-1} s^{-1}). During the first 40 s of the race the O_2 uptake rose roughly linearly by time at a rate of ≈ 0.5 ml kg^{-1} min^{-1} s^{-1} (0.35 µmol kg^{-1} s^{-2}; Figure 2a). During the next 20 s there was little change before a final increase of 6 ml kg^{-1} min^{-1} to the peak value of 48.1 ± 1.8 ml kg^{-1} min^{-1} (35.8 ± 1.3 µmol kg^{-1} s^{-1}; 83% of the maximal O_2 uptake) was seen at the end of the race. There were no major differences in this pattern between the different skiers.

The accumulated O_2 uptake during the race was 43.5 ± 1.6 ml kg^{-1} (1.94 ± 0.07 mmol kg^{-1}), and the O_2 uptake averaged over the race was 36.8 ± 1.2 ml kg^{-1} min^{-1} (27.4 ± 0.9 µmol kg^{-1} s^{-1}; 63% of the maximal O_2 uptake).



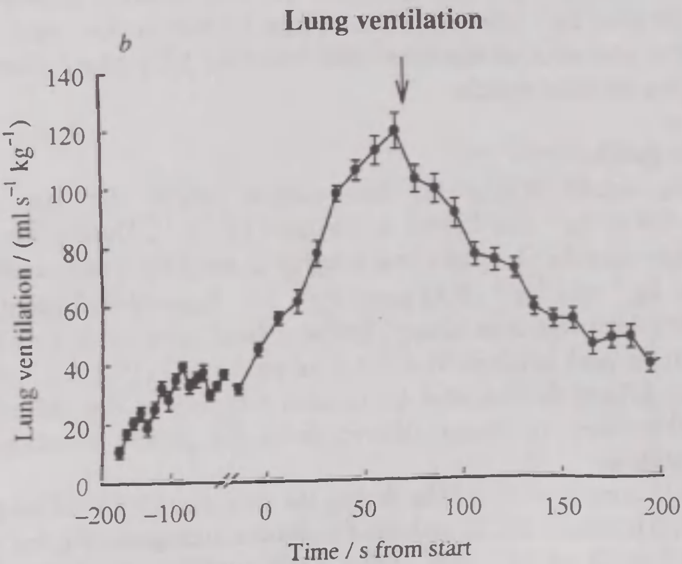


Figure 2. *a* the O_2 uptake and *b* the lung ventilation before, during and for 2 min after a giant slalom test race. The arrows mark the end of the race. The data are mean ± SEM of seven (O_2 uptake) and eight (lung ventilation) top male junior skiers; data on the O_2 uptake from one skier were lost.

The lung ventilation during the last minute before the race was 9.1 ± 0.4 ml kg^{-1} s^{-1} (42 ± 2 L min^{-1}). The lung ventilation rose roughly linearly by time during the race to a peak of 31.4 ± 1.3 ml kg^{-1} s^{-1} (143 ± 4 L min^{-1}) at the end of the race (Fig. 2b). The ratio between the lung ventilation and the O_2 uptake was 28 ± 1 L L^{-1} before the race, and the ratio rose continuously to 41 ± 1 at the end of the race. The lung ventilation thus rose relatively more than the O_2 uptake did, reflecting a hyperventilation.

Total energy release

The accumulated O_2 uptake of 1.94 mmol kg^{-1} corresponds to an aerobic ATP-production of 12.6 mmol ATP kg^{-1} body mass, assuming that 1 mol of O_2 leads to regeneration of 6.5 mol of ATP. The anaerobic ATP-production of 25.3 mmol ATP kg^{-1} corresponds to an anaerobic ATP-production of 6.3 mmol ATP kg^{-1} body mass if the working muscle mass was 25% of the body mass. Thus, the total ATP-production was 18.9 mmol ATP kg^{-1} body mass, which was released in 70.1 s, that is at an average rate of 0.27 mmol ATP s^{-1} kg^{-1} body mass. This value corresponds to an O_2-consumption of 41 μmol kg^{-1} s^{-1} or 56 ml O_2 kg^{-1} min^{-1} (96% of the subjects' maximal O_2 uptake during treadmill running). Moreover, these data suggest that the aerobic ATP-production amounted to 67% of the total energy release, while the anaerobic ATP-production provided 33% of the total.

Leg strength

The subjects' maximum leg strength taken from their performance in a full squat lift was 141 ± 7 kg or 1.87 ± 0.10 kg kg^{-1} body mass, and that value correlated with the race time ($r = -0.80$, $P = 0.03$; Figure 3a), meaning that the strongest skiers were the fastest ones. The maximum leg strength also correlated with the total energy release during the race ($r = -0.85$, $P = 0.03$; Figure 3b), and the relationship did not change much if the energy release was expressed as the average rate during the race ($r = -0.80$, not shown). Thus our data suggest that the strongest skiers also had the lowest energy release. There were no other statistically significant correlations between the different entities determined in this study.

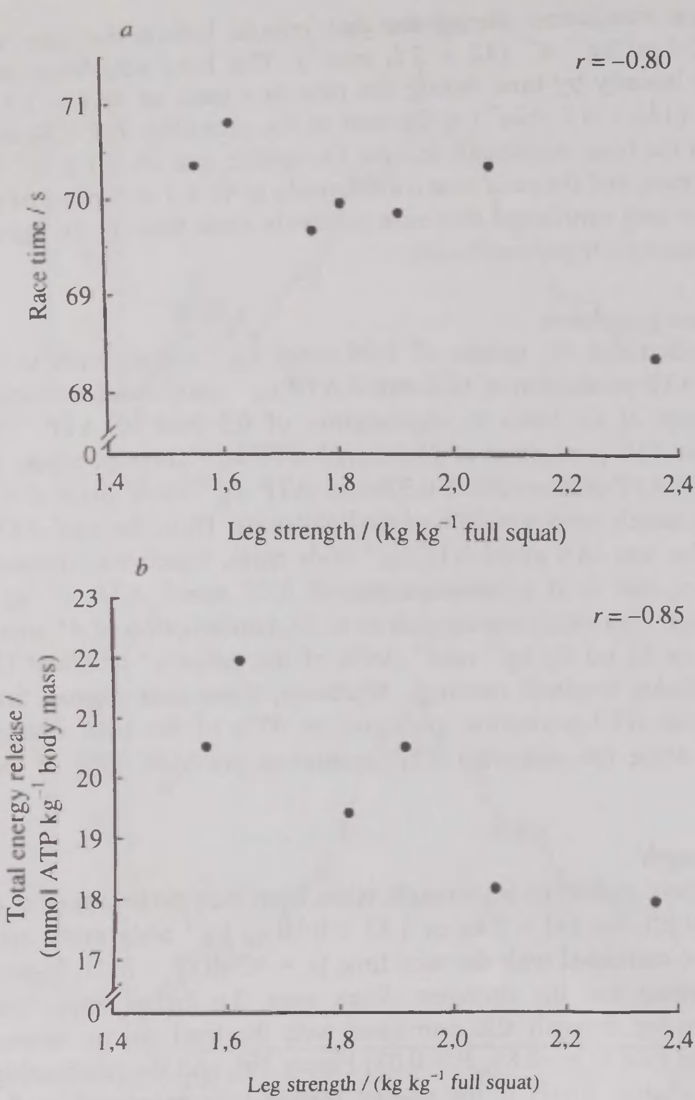


Figure 3. *a* the race time and *b* the total energy release versus the leg strength taken as the maximal lift of a full squat. The data are from seven (*a*) and six (*b*) subjects who carried out at giant slalom test race. Data from one and two other subjects were not obtained. Both entities correlate negatively with the leg strength.

DISCUSSION

The main findings in this study were first that aerobic processes dominated the energy release in the giant slalom race. Second, the O_2 uptake during the race did not reach the subjects' maximal O_2 uptake. Third, the major part of the moderate anaerobic energy release seen came from lactate production. Consequently, the total rate of energy release did not exceed the rate corresponding to the subjects' maximal O_2 uptake. Finally, the race time correlated with the maximum leg strength.

Anaerobic energy release from lactate production and breakdown of phosphocreatine

The lactate production during the giant slalom race that lasted 70 s was 11 mmol kg^{-1} wet muscle mass (wmm). That value is similar to what has been found during downhill skiing [27]. The breakdown of phosphocreatine for our subjects was 8 mmol kg^{-1}. Consequently, the total anaerobic ATP-production was 25 mmol kg^{-1} wmm. That value is only 45% of that found for 60–70 s bicycling to exhaustion [21, 30] and around 60% of that found after 30 s sprints of running [7, 23] or bicycling [21]. In fact, the lactate production as well as the phosphocreatine breakdown during 6–12 s bicycling to exhaustion is as large as that found in the present study [5, 11, 15]. These findings are summarized in Figure 4.

The low lactate production during the race also means that lactate was produced at a rate of only 0.16 mmol s^{-1} kg^{-1} muscle. That rate is only 40% of that found during exhausting bicycling of the same duration [21, 30]. The rate of lactate production during 400 m track running may be twice as high as that seen during this giant slalom race [8]. Moreover, the rate of lactate production seen here was only 19% of that seen during a bicycle sprint [15].

The concentration of glucose-6-phosphate rose during the race to 2.3 mmol kg^{-1} wet muscle mass. After exhausting bicycling of the same duration values twice as high have been found [13]. Thus, neither the rate of lactate production nor the accumulation of lactate and glucose-6-phosphate were high compared with that found in other studies on shortlasting, exhausting exercise. All these observations

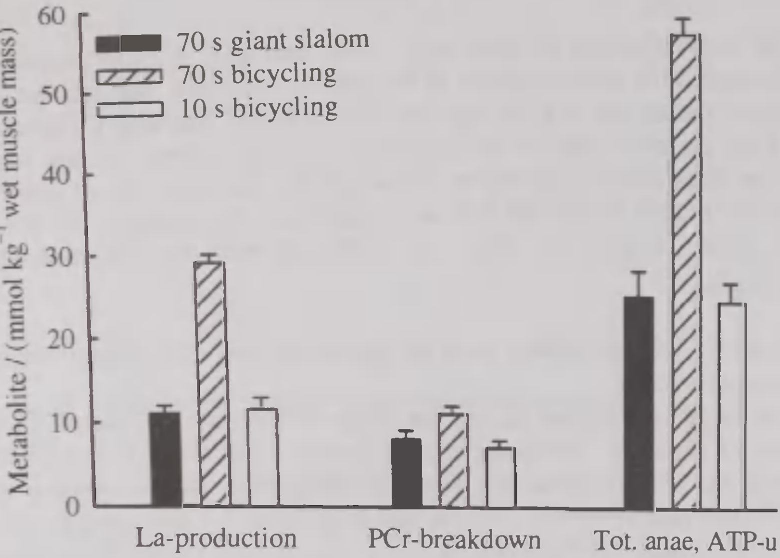


Figure 4. Lactate production, phosphocreatine breakdown, and the total anaerobic ATP-production in muscle during the giant slalom race, 70 s bicycling to exhaustion [21], and during 10 s bicycling to exhaustion [15]. The total anaerobic ATP-production is given in ATP-units.

suggest that the anaerobic system of energy release was far from being maximally stressed in this study. In line with this there were considerable reserves of phosphocreatine at the end of the race, which would probably not have been seen if the energy delivery had been stressed maximally. The current opinion holds that alpine skiing is an exercise demanding a very large anaerobic energy release [12, 25, 28]. However, these latter opinions are not based on direct measurements of anaerobic metabolites in the muscles. In fact, the authors of one study point out that the methodology they used has clear limitations [25]. The fact that we, basing our conclusions on changes in the concentrations of lactate and phosphocreatine, have arrived at different conclusions than others who used the blood lactate concentration and the O_2 debt adds further support to the idea that these latter parameters may not be adequate measures of the anaerobic energy release, at least not for exercising humans. Our data also suggest that the alactic anaerobic energy release during giant slalom is quite limited.

Aerobic energy release

The oxygen uptake rose more or less continuously during the race and peaked at 83% of the maximal O_2 uptake near the end. The oxygen uptake averaged over the whole race was 37 ml kg^{-1} min^{-1} (63% of the $\dot{V}O_2$ max). Our data on the O_2-uptake are similar to those of others, and we extend their data by carrying out continuous measurements throughout the track compared with their results based on one [28] or three [25] samples in Douglas bags during a race.

Our data suggest that the subjects did not exercise at an intensity higher than that corresponding to the maximal O_2 uptake, and consequently the relative contribution from aerobic processes was as much as 67% of the total energy release. Others have suggested that the exercise intensity of giant slalom may be 120% [25] or 160% of the maximal O_2-uptake [28]. Saibene and coworkers [25] showed that the O_2-uptake rose faster when running at a speed corresponding to 120% of the maximal O_2-uptake than during a giant slalom race. They therefore suggested that a large static component in the leg muscles may impede the blood perfusion and thus slow the O_2-uptake during alpine skiing. For example, in very intense exercise one would expect values of 90–100% of the maximal O_2 uptake within 60–70 s [19]. Hill and Rowell [10] found on the other hand that when subjects ran on a treadmill at a speed corresponding to their maximal O_2 uptake, it took 2.5 min before the O_2 uptake reached 95% of the maximal O_2 uptake and 4 min before they reached their maximal O_2-uptake. The time course of the O_2-uptake in our study is in fair agreement with their data and with data on the time course of the O_2 uptake during > 4 min running to exhaustion (unpublished observations). This further supports the idea that the total rate of energy release in our study was not larger than that corresponding to the maximal O_2 uptake.

The O_2 uptake peaked at 83% of the maximal O_2 uptake near the end of the race. The O_2 uptake is the product of the blood flow and the arterio-venous (a–v) difference, and during intense exercise the a–v difference of O_2 is almost always close to maximum. Since the O_2 uptake peaked at a value 17% less than the maximum, the leg blood flow was probably also quite large. These considerations suggest giant slalom does not restrict the leg blood flow much compared with that of running, at least not for our well-trained subjects. Thus, although giant slalom is dominated by eccentric movements while bicycling and running are mainly concentric in nature, it may still be acceptable to compare the energy release during these different activities.

The O_2-uptake nearly levelled off for around 20 s for all of the subjects during the latter half of the race before increasing again near the end. We have no explanation for this finding, and we do therefore not know whether it has principal or practical consequences.

Leg muscle strength

The strongest skiers were the fastest ones. That observation is in line with current knowledge on alpine skiing [1, 3, 4, 12]. It is nevertheless interesting to note that the effect was apparent even in this small group of quite homogenous top junior skiers. The leg strength also correlated negatively with the total energy release. This observation is to our knowledge new. It may be that strong skiers may carry out the turns more easily than weaker ones and that they thus ski more economically and faster. Our study is based on only eight subjects, and we lost some data on one or two of the subjects. Moreover, we have not measured their working muscle mass. Thus, this topic may deserve further study before firm conclusions are drawn.

Muscle fiber types and muscle Na,K-pump concentration

All of the subjects had more than 50% of type 1 fibers in their knee extensor muscles. One might think that the muscles of athletes in a shortlasting, intense type of exercise like alpine skiing were dominated by type 2 fibers. However, high forces but slow muscle shortening characterize alpine skiing [3, 4]. Moreover, the properties of different human fiber types may not differ as much as that of rat muscles [29]. Finally, large volumes of regular training may perhaps increase the proportion of type 1 fibers.

The concentration of Na,K-pumps in the skiers' knee extensor muscle is among the very highest seen for human subjects. This enzyme may have a large excess pumping power [17], and it is therefore not known whether the high concentrations seen here is of physiologic importance or has any importance for success in alpine skiing.

Methodological questions

The muscle biopsies taken at the end of the race were taken with thrucut needles. We readily got 15–20 mg of muscle tissue from each biopsy, and that is enough material for several biochemical analyzes on each biopsy. The biopsies taken by this needle immediately after the race contained far less blood than in those taken by the traditional Bergström needles at rest. Another advantage with the thru-cut needle is that the biopsies were taken as a single shot thru the skin and without use of local anesthesia. This is particularly useful in field experiments. A limitation with the thru-cut needle is that the biopsies are obtained as a long, thin cylinder that may not be used for histochemical analyses. We therefore used the biopsies taken at rest with the Bergström-type needle for our histochemical analyses.

We measured the oxygen uptake in this study by the Metamax I portable metabolic analyzer. The whole instrument including a back-pack with batteries, mask, tubing, and telemetry weighed only 3.1 kg and was readily mounted on the subject's back. Carrying the instrument in a back-pack caused no problems for the subjects and allowed us to do continuous measurements of the O_2 uptake during the race. We obtained reliable results, at least when the delay caused by the instrument's build-in averaging was reduced by numeric techniques [14, 18]. A separate control study has shown that the Metamax measures the O_2 uptake and the lung ventilation reliably but that this instrument like most portable analyzers does not measure the respiratory exchange ratio properly [18]. We have therefore not reported any data on the respiratory exchange ratio in this study.

We experienced one problem with our measurements. Since the subjects skied as fast as possible and thus cut every corner, the Metamax instrument hit the poles in a number of the gates. This cracked its protective plastic cover a little by little, and for the last skier the data were lost because the gas sensors were broken. If the instrument had had an extra protective cover, for example of polystyrene, bubble wrap, or other materials in common use for protection during transportation, that would probably prevented the failure seen in our study.

When we calculated the energy release, we did not include possible use of stored oxygen. Oxygen stores in the venous blood is the largest source of stored O_2 (see [20] for details). This is probably a minimal problem since even at rest this amounts to around 0.25 mmol kg^{-1} body mass. Moreover, the O_2 uptake was quite high before the race, meaning that the O_2 concentration of venous blood may have been reduced below the rest level before the race started.

We also assumed that the working muscle mass was 25% of the body mass for our subjects. The anaerobic energy release contributed relatively little to the total, and separate calculations show that if we assume a working muscle mass equal to 30% of the body mass, that would not violate our conclusions (not shown). Thus, our conclusions are quite robust against possible errors in the assumed working muscle mass.

The phosphocreatine concentration at rest was only 15 mmol kg^{-1}. This could mean that we have underestimated the use of phosphocreatine during the race. However, phosphocreatine contributed little to the total energy release, and even a large relative error in the amount of phosphocreatine used have little influence on the total energy release. The muscle biopsies were frozen around 25 s after the race. During that period the phosphocreatine concentration in muscle may raise by ≈1 mmol kg^{-1} [21]. This is a small error. We have not included release of lactate to the blood during the race in our calculations. Lactate is released from the muscles at a slow rate even during intense bicycling, amounting to ≈6% of that produced during a 2 min ride [22]. Since the giant slalom race lasted only 70 s and the leg perfusion may have been somewhat less than that during bicycling, the release of lactate was probably less than that during bicycling. Thus, the major part of lactate produced probably remained within the muscles.

For practical reasons the maximal O_2 uptake and the maximum leg strength were measured a couple of months before or after the race. The maximal O_2 uptake measured in this study is typical for that of good alpine skiers, as reviewed elsewhere [2]. We cannot rule out that the leg strength and the maximal O_2 uptake changed somewhat during the season, but we do not expect major changes in these parameters during the competition season. That assumption is also supported by data of Bosco and coworkers who found that the performance on several neuromuscular performance tests rose during the dry-season period (June to October) and remained high during the competition season period (October to April) for elite alpine skiers [6]. In additions, our conclusions drawn are robust against moderate variations in these parameters.

We used top junior alpine skiers using modern carving skies and a track according to the standards for World Cup competitions. No one has as far as we know carried out a similar study. Admittedly, two former studies used tracks according to the standard of the International Skiing Federation at that time [25, 28]. It is not known whether those tracks would fit the standards of today, nor is it known to what extent possible differences in the tracks, athletes, and skis used will influence the results.

Conclusions

Our data suggest that the energy release during a giant slalom race, which lasts a little more than 1 min, is not very high compared with that of running and bicycling. Moreover, aerobic processes account for the major part of the energy release, and the alactic anaerobic energy release appeared to be quite limited. Finally, the leg muscle strength was related to the race time and to the total energy release.

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Roar Aaserud is presently dean of Stinta junior highschool in Arendal, Norway.

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Correspondence to:
Petter Gramvik
Agder University College
Faculty of Health and Sports
Service box 422
N-4604 Kristiansand
Norway

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PHYSICAL LOAD AND PHYSICAL FUNCTIONAL CAPACITY IN GREEK-ROMAN WRESTLERS OVER THE FOUR YEAR OLYMPIC CYCLE

K. Milasius, L. Tubelis, J. Skernevicius
Vilnius Pedagogical University, Vilnius, Lithuania

ABSTRACT

The aim of this study was to analyze the structure and content of the training during Olympic four-year cycle in top-class Greek-Roman wrestlers and to assess the course of adaptation to physical loads and functional capacity over this period. The study involved 12 members of the Lithuanian national team – wrestlers of different weight categories. We analyzed the physical load endured by all wrestlers over the period 2001–2004 according to the scheme of members of the Olympic team. Body mass, muscle and fat mass, muscle and fat mass ratio (FMMI), psychomotor response time (PRT) and central nervous system liability (CNSL) were measured. The hexagonal jump test was used to determine mobility. Muscular power in different energy production zones was determined. The efficiency of anaerobic alactic energy production mechanisms was established from single muscular contraction power (SMCP), anaerobic alactic muscular power (AAMP) and maximum strain performance on a veloergometer for 10s. Mixed anaerobic alactic and glycolytic power was under a 30-second maximum strain (Wingate test). To make the comparison of the physical development and physical functional capacity indices more informative, the method of their normalization was employed. The profile of normalized indices is more negative in lighter wrestlers. Only one relative AAMP index was closer to the zero (mean) index. In the athletes of medium weight categories, all indices of physical and functional capacity were closer to the zero limit. In the heavy weight wrestlers, these indices were slightly off the zero limit, implying that the light weight wrestlers should give more attention to muscular power training.

Key words: Greek-Roman wrestling, Olympic four-year cycle, adaptation, physical and functional capacity

INTRODUCTION

Greek-Roman wrestling in Lithuania is gaining popularity. In many countries this type of wrestling has old traditions, nevertheless, also Lithuanian wrestlers over the recent years have attained rather significant success in the World's and Europe's adult, junior and juvenile championships. In the 2004, three Greek-Roman wrestlers from Lithuania participated in the Athens Olympic Games.

The further progress of Lithuanian Greek-Roman wrestlers should be based on the search of new talents, improved technical and tactical preparation of wrestlers, optimal physical loads at various preparatory stages, reliable information about the dynamics of the wrestlers' physical and functional capacity dynamics. These constituent elements of sportsmen's training are indispensable for effectively managing the wrestlers' training process, prognosticating and adjusting their physical abilities, recovery and adaptation [14, 21].

Wrestling as a specific branch of sport is characterized by aciclicity and encompass static strain elements, motion with different and constantly changing moments of power, postures that impede the functioning of organs and systems and imply a constant change of situations [9, 11, 13]. However, it is not yet clear which indices of the physical and functional power are best to reflect bodily adaptation in wrestlers.

Therefore, in improving the methods of wrestlers' training, of great significance is the synthesis of the coach's experience and scientific knowledge, which needs to be constantly upgraded and practically checked loads of training give the desirable results and induce the progress of the sportsmen's physical and functional capacity [3, 16]. However, works to deal with these problems of training highly-skilled Greek-Roman wrestlers and their adaptation to physical loads are not numerous. There is a particular shortage of studies on the training of such sportsmen over the Olympic cycle.

The aim of this study was to analyze the structure and content of the Olympic four-year cycle in training top-class Greek-Roman wrestlers and to assess the course of adaptation to physical loads and functional capacity dynamics over this period.

MATERIAL AND METHODS

The study involved 12 members of the Lithuanian national team – wrestlers of different weight categories. The weight categories were divided into three groups: group 1 – up to 55, 60 and 65 kg, group 2 – up to 74 and 84 kg, and group 3 – up to 96 and 120 kg. Each group contained 4 subjects. We analyzed the physical load endured by all wrestlers over the period 2001–2004 according to the scheme of training members of the Olympic team. The volume of physical work reflects the "external" aspect of the load, while bodily response of the load shows its "internal" aspect. It is not difficult to determine the bodily response to a load; a more intricate task is to assess the load during a competition. The intensity of physical load was assessed by 1–8 points. 1–2 points – 108–131 b/min, 3–4 points – 132–161 b/min, 5–6 points – 162–179 b/min, and 7–8 points – load at a heart rate of 180–192 b/min.

Every sportsman was examined 3 to 4 times each year of the Olympic cycle. Such indices of physical development as body mass, muscle and fat mass, muscle and fat mass ratio (FMMI) [18], psychomotor response time (PRT), central nervous system liability (CNSL) in regulating movement frequency per 10s. The hexagonal jump test was used to determine mobility [6]. Muscular power in different energy production zones was determined. The efficiency of anaerobic alactic energy production mechanisms was established from single muscular contraction power (SMCP) [5] anaerobic alactic muscular power (AAMP) and maximum strain performance on a veloergometer for 10s [20].

Mixed anaerobic alactic and glycolytic power was measured using a 30-second maximum strain (Wingate test) [12]. The circulatory and respiratory capacities were assessed according to heart rate (HR) in a lying position. Aerobic capacity was measured with the gas analyzer ERGOOXYSCREEN by increasing load until the critical intensity limit, till VO_2 max was reached [19].

Means $(\overline{X})$ and their representative error $(S\overline{x})$ were calculated. Pearson's test was applied to establish interrelations among the indices. The profile of the obtained indices was determined by the index normalization method. Student's t-test was used to assess the differences among the groups. Significance was set at $p < 0.05$.

RESULTS

The thoroughly elaborated and strictly observed technological process of training Lithuanian Greek-Roman wrestlers allowed them to win the gold and silver medals at the world youth championship and bronze medals at the European adult championship and bronze medals at the European adult championship. Analysis showed that over the four-year Olympic cycle the parameters of physical load kept increasing, the top level (1154 hrs) being attained in the fourth year. That year the number of trainings increased till 192 and 485 hours was allotted to special physical training (Table 1).

Analysis of the sportsmen's muscle and fat mass showed that wrestlers of higher weight categories had higher muscle mass (Table 2). However, the latter had higher indices of circulatory and respiratory capacity. The highest relative muscular power in various energy production zones was developed by wrestlers from the 74 and 84 kg weight categories (Table 3). Special performance indices under 10-s and 30-s workload in these wrestlers reached 12.11 ± 0.59 and 9.08 ± 0.18 W/kg.

We assessed also the informativeness of the Greek-Roman wrestlers' physical development and functional capacity indices. The results showed (Table 4) that the correlations were highest between body and muscular mass, between body mass and right/left hand force ($r = 0.721$ and $r = 0.741$). The correlation was rather close also between the indices that characterize the state of swiftness-force components such as SMCP, AAMP and psychomotor response time ($r = 0.706$). The 10-s workload power index was also closely correlated with body mass and muscle mass. Worth noting is a close correlation between 10-s and 30-s workload power (r = 0.958). We did not determine a significant correlation between the indices of 10-s workload power and SMCP, which are the main indices of muscular power under a short-lasting workload. However, with increasing the workload duration the correlation becomes strong: it is closer between the 10-s workload power and AAMP (r = 0.408).

Table 1. Training load characteristics of the Lithuanian Greek-Roman national team wrestlers

Workload	Olympic cycle				
	1st year	2nd year	3rd year	4th year	Total
Contest days, n	28	45	66	53	192
Competition, n	15	29	36	31	109
Training days, n	141	236	260	252	889
Training rounds, n	298	580	555	592	2025
General physical training, %	58	60	54	58	58
Special physical training, %	42	40	46	42	42
Special physical training, hours	272	325	450	485	1532
Training duration, hours	648	812	978	1154	3742
Mean intensity (points)	6.4	6.2	6.6	7.2	6.6

Table 2. Physical development and some functional capacity indices of Greek-Roman wrestlers from different weight categories $(\bar{X} \pm Sx)$

Weight group	Body mass, kg	Muscle mass, kg	Fat mass, kg	Fat muscle mass index	Handgrip strength, kg		VO_2 max ml/kg/min
					Right	Left	
Up to 55; 60; 66 kg n = 4	63.25±2.56	33.40±1.28	7.05±0.29	4.72±0.24	36.25±1.65	32.75±1.79	60.33±1.07
Up to 74; 84 kg n = 4	73.60±1.33	38.95±1.01	8.55±0.56	4.64±0.40	45.50±3.20	45.75±3.51	56.70±0.67
Up to 96, 120 kg n = 4	91.67±2.34	50.42±2.40	9.00±0.35	5.64±0.46	49.00±4.64	47.75±5.07	52.25±1.30
p I–II							<0.05
p I–III	<0.001	<0.001					<0.05
p II–III	<0.001	<0.01					<0.01

Table 3. Muscular power and psychomotor functional indices of Greek-Roman wrestlers from different weight categories $(\overline{X} \pm Sx)$

Weight group	SMCP, W/kg	AAMP, W/kg	PRT, ms	MF, times/10s	Agility, s	Power			
						10s, W	10s, W/kg	30s, W	30s, W/kg
Up to 55; 60; 66 kg n = 4	24.03±2.61	19.49±1.12	184.75±6.76	81.75±7.61	13.6±0.54	685.1±20.64	10.80±0.12	544.1±12.16	8.58±0.22
Up to 74; 84 kg n = 4	27.90±0.53	18.87±1.03	180.25±12.88	84.50±9.56	14.12±1.17	902.5±96.5	12.11±0.59	674.5±25.5	9.08±0.18
Up to 96, 120 kg n = 4	24.25±3.50	17.78±0.40	173.50±5.56	72.75±4.80	12.94±0.50	1029.5±38.83	11.27±0.30	777.0±47.9	8.51±0.46
p I–II						<0.01	<0.01	<0.001	
p I–III						<0.001		<0.001	
p II–III									

Table 4. Interrelation among physical development, physical and functional capacity indices in Greek-Roman wrestlers of different weight categories

Indices		Body mass, kg	Handgrip strength, kg		Muscle mass, kg	VO_2 max ml/kg/min	SMCP, W/kg	AAMP, W/kg	PRT, ms	MF, moves/ 10s	Agility, s	Power			
			R	L								10s, W	10s, W/1kg	30s, W	30s, W/1kg
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Body mass, kg		1													
R hand strength, kg		0.694**	1												
L hand fstrength, kg		0.697**	0.924***	1											
Muscle mass, kg		0.982***	0.721**	0.741**	1										
VO_2max, ml/ kg/min/		–0,811***	–0,517*	–0,550*	–0,835***	1									
SMCP, W/kg		0.199	0.417	0.464	0.223	0,156	1								
AAMP, W/kg		–0.275	0.112	0.115	–0.268	0,448	0.130	1							
PRT, ms		–0.206	0.189	–0.027	–0.268	0,456	0.151	0.511*	1						
MF, moves/10s.		–0.297	–0.002	0.210	–0.275	0,339	0.151	0.313	0.122	1					
Agility, s		–0.180	0.247	–0.011	–0.231	0,356	0.391	0.104	0.706**	–0.030	1				
Power	10s. W	0.812***	0.577*	0.669**	–0,484	0.257	0.190	–0.146	–0.367	0.026	–0.248	1			
	10s. W/1kg	0.169	0.074	0.103	0,135	0.250	0.262	0.408	0.273	0.369	0.213	0.555*	1		
	30s. W	0.785**	0.523*	0.591*	–0,584*	0.245	–0.052	–0.248	–0.414	–0.059	–0.303	0.958***	0.496	1	
	30s. W/1kg	–0.314	–0.332	–0.430	0,128	0.141	–0.446	0.285	0.382	0.088	0.229	–0.107	0.519*	0.067	1

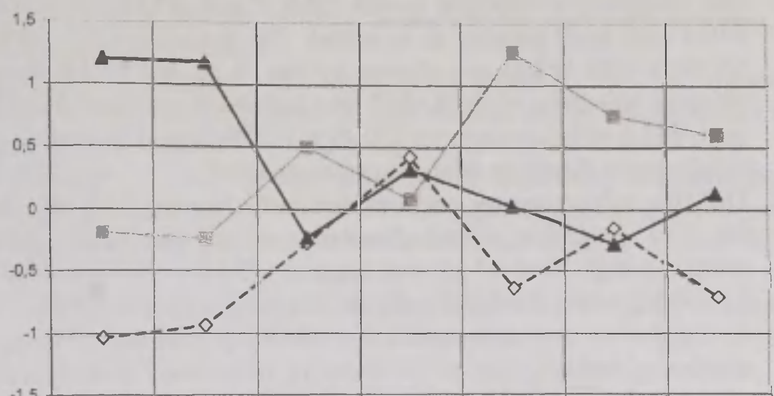
Note:
*Statistically significant p<0.05 (r>0,514)
**Statistically significant p<0.01 (r>0,661)
***Statistically significant p<0.001 (r>0,815)

DISCUSSION

One of the most important criteria of sportsmen's body mass is muscular mass. Numerous investigations have shown that muscular force developing exercises may lead to muscular hypertrophy [8, 10]. A comparison of the muscular mass of the sportsmen observed in the present study and of untrained people [2] shows the wrestlers' muscular mass in different weight categories comprises 52–55% of the total body mass, compared to 45–47% in untrained people. In wrestlers, fat mass is the primary reserve for decreasing the body mass to keep within one's weight category. Analysis of the muscle and fat mass shows that in the lighter and medium weight categories it is similar and being higher in heavier wrestlers [1]. Nevertheless, in heavier wrestlers the relative power of muscular contraction under a short-lasting workload is lower than in lighter wrestlers. For wrestlers, the physiological indices are of particular significance. In them, psychomotor response time and 10-s movement frequency, which shows the central nervous system's liability, was of a medium level and showed no essential differences among the groups.

As is shown by Bangsbo [4], anaerobic capacity is important also for special endurance in sport disciplines characterized by a high power of performance. In Greek-Roman wrestlers, a large portion of training load is performed above the anaerobic metabolism threshold. Therefore, the larger the workload portion performed above this limit, the higher the requirements to aerobic capacity [15, 17]. The functional circulatory and respiratory capacity was higher in lighter wrestlers; in Coyle's opinion [7], this also favors anaerobic glycolytic capacity.

To make the comparison of the physical development and physical functional capacity indices more informative, the method of their normalization was employed (see Fig. 1). Figure can be seen that the profile of normalized indices is more negative in lighter wrestlers. This type of profile is indicative of the true position of the indices in the general group. Only one relative AAMP index was closer to the zero (mean) index. In the athletes of medium weight categories, all indices of physical and functional capacity were closer to the zero limit.



	Body mass, kg	Muscle mass, kg	SMCP, W/kg	AAMP, W/kg	10s, W/kg	30s, W/kg	Roufier index
I	-1,04	-0,94	-0,27	0,42	-0,64	-0,16	-0,71
II	-0,20	-0,24	0,50	0,08	1,26	0,76	0,60
III	1,20	1,18	-0,23	0,32	0,03	-0,29	0,12

Figure 1. Profile of normalized physical development, physical and functional capacity indices of Greek-Roman wrestlers

In the heavy weight wrestlers, these indices were slightly off the zero limit, implying that the light weight wrestlers should give more attention to muscular power training. It is possible to suppose that the light weight wrestlers avoided developing muscular mass at the expense of developing the aerobic zone, their circulatory capacity being the highest, and thus neglected developing short-term power.

CONCLUSIONS

1. Over the Olympic preparatory cycle, the Greek-Roman wrestlers performed a large-volume physical load to which their body became maximally adapted. Over this period, the sportsmen's training took 889 days, with 2025 training rounds and 192 contest days. The sportsmen attained good results in the Europe adult and junior championships and Olympic Games.

2. The sportsmen's muscular power (SMCP and AAMP) reached a rather high level peculiar to wrestlers. The highest relative SMCP (27.90 ± 0.53 W/kg) was shown by the 74 kg and 84 kg weight category wrestlers, while AAMP was highest in wrestlers from the up to 66 kg weight categories (19.49 ± 1.22 W/kg). The state of the psychomotor functions of the sportsmen varied.
3. The 10-s veloergometer performance in the anaerobic alactic and the 30-s anaerobic alactic-glycolytic energy production zones reached a high level which was highest (12.11 ± 0.89 and 9.08 ± 0.18 W/kg, respectively) in medium weight category wrestlers.
4. A correlation analysis revealed a close interrelation among a number of indices, first of all those of body mass and muscular power under workload of various duration, however, no reliable relation with the relative 1 kg body mass indices was found.

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Correspondence to:
Kazys Milasius
Studentu 39, LT–08106, Vilnius
Lithuania

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MOTOR PERFORMANCE CHARACTERISTICS IN PATIENTS WITH MILD-TO-MODERATE PARKINSON'S DISEASE AND HEALTHY CONTROLS

K. Noorvee[1], D. Uueni [1], J. Ereline[1,3], H. Gapeyeva[1,3], P. Taba[2], M. Pääsuke[1,3]

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

[2] Department of Neurology and Neurosurgery, University of Tartu, Tartu, Estonia

[3] Estonian Centre of Behavioural and Health Sciences, Tartu, Estonia

ABSTRACT

This study compared motor performance characteristics in patients with Parkinson's disease (PD) and nondisabled age- and gender-matched controls and measured the relationship between objectively assessed motor performance characteristics and scores of Unified Parkinson Disease Rating Scale (UPDRS) in PD patients. Twelve patients with mild-to-moderate PD (5 women and 7 men) and 12 nondisabled controls participated in this study. Postural sway during 30-s standing with eyes opened and closed was tested on two force platforms. Isometric maximal voluntary contraction (MVC) force and rate of force development (RFD) of the knee extensor (KE) muscles was measured using isometric dynamometer. Gait characteristics (cadence, stride length, mean velocity) were tested using opto-electronic motion analysis system. PD patients had lower ($p < 0.05$) RFD of KE muscles, stride length and mean velocity of gait compared with controls. MVC force of KE muscles, postural sway and cadence during gait did not differ significantly in measured groups. Spearman correlation analysis demonstrated positive correlations at medium level between UPDRS total score, age of subject and postural sway during standing with open eyes ($p < 0.1$). UPDRS motor score positively correlated at medium level with age of subject and negatively with MVC force of the KE muscles and stride length during gait ($p < 0.1$). Strong negative correlations ($p < 0.01$) were found between UPDRS total score, MVC force and RFD of the KE muscles, and stride length during gait and mean velocity of gait ($p < 0.05$). We concluded that motor performance in PD patients was lowered and that UPDRS is a relevant tool for measurement of motor performance in Parkinson's disease.

Key words: Parkinson's disease, UPDRS, gait, muscle strength, postural sway

INTRODUCTION

Parkinson's disease (PD) is a polyetiologic neurodegenerative disease, influencing mainly older subjects. The main clinical symptoms in PD are tremor, rigity, slowness and difficulty of initiating movements, shuffling gait, a stooped forward posture, marked postural instability and freezing phenomena [3, 18]. Patients with PD perform movements more slowly [8], they have impaired balance, co-ordination of movements and activation of skeletal muscles as compared with age-matched healthy subjects. They also have a limited range of motion and increased reaction time. In PD patients, the trunk is flexed during gait, often they do not show a plantigrade walking pattern and co-movements of arms during gait [14]. The rotational movements of the trunk during gait are reduced in PD patients [5]. The muscle strength is also reduced in PD patients, whereas the decrease in muscle strength is asymmetrical, more pronounced in extensor than flexor muscles and is affected by the speed of movements and the type of muscle contraction [14, 16]. All factors mentioned above affect the daily life and overall motor performance in PD patients. The Unified Parkinson's Disease Rating Scale (UPDRS) is a rating tool that covers different aspects of PD and enables to follow the longitudinal course of PD. It assesses six primary areas of disability associated with PD [4]. The UPDRS is applied by a wide range of users. The Motor

Examination section in UPDRS provides a detailed assessment of PD motor impairment based on physical examination of the patient.

The aims of the present study were (1) to compare motor performance characteristics in patients with mild-to-moderate PD and nondisabled age- and gender-matched controls, and (2) to measure the relationship between objectively measured motor performance characteristics and UPDRS scores (total and motor) in PD patients. More specifically, we assessed the force-time characteristics of the knee extensor (KE) muscles, postural sway, and temporal and spatial characteristics of gait.

MATERIAL AND METHODS

Subjects

Twelve patients with idiopathic PD (5 women and 7 men, with mean ± SE age 67.4 ± 1.2 years, height 1.67 ± 0.03 cm, body mass 73.7 ± 4.6 kg and duration of the disease 8.1 ± 3.4 yrs) and 12 nondisabled control subjects (5 women and 7 men with mean ± SE age 66.8 ± 1.1 years, height 1.68 ± 0.02 cm and body mass 75.0 ± 3.5 kg) took part in this study. The anthropometric characteristics did not differ significantly in PD patients and controls. Patients with PD were recruited from the Department of Neurology, Tartu University Hospital. Inclusion criteria were diagnosis of idiopathic PD confirmed by the neurologist, with a disease-severity rating of from stage II to III (mild-to-moderate PD) on the Hoehn and Yahr's scale [7]. All patients were had adequate comprehension of instructions. They were medicated with ordinary anti-parkinsonian drugs. All subjects have signed the informed consent and the study was approved by the University Ethics Committee for Human Studies.

Unified Parkinson Disease Rating Scale (UPDRS)

A qualified neurologist administered the UPDRS. During the assessment, only the patient and neurologist were in the room. The higher the result of UPDRS, the more expressed is the Parkinson's disease of the patient.

Testing of isometric force-time characteristics of the knee extensor muscles

The subjects sat in a custom-made dynamometric chair with the knee and hip angles of dominant leg equal to 90° and 110°, respectively. The body position of the subjects was secured by three Velcro belts placed over the chest, hip and thigh. The unilateral knee extension force was recorded by a chair-fixed standard strain-gauge transducer (DST 1778, Russia) connected with the plate by rigid bar. The strain-gauge transducer pad was placed approximately 3 cm above the apex of the lateral malleolus on the anterior aspect of the leg. During testing isometric force–time characteristics of the KE muscles the subject was instructed to react to the visual stimuli (lighting of the signal lamp, placed 1.5 m from the subject) as quickly and forcefully as possible by extending the leg against a cuff fixed to a strain gauge system, to maintain the maximal effort as long as the signal was on (2 s) and to relax the muscles after the disappearance of the signal. Three attempts were carried out and the trial with higher isometric maximal voluntary contraction (MVC) force was used for further analysis. A rest period of 2 min was allowed between the attempts. The following characteristics were calculated: MVC force – the highest value of isometric force generated and rate of isometric force development (RFD) – the first derivate of force development (dF/dt) at 0.2 s after the initiation of isometric force during MVC.

Postural sway testing

Postural sway during standing was evaluated with two force platforms (Kistler 9286A, Switzerland). Subjects stood barefoot on 2 platforms with their feet 10 cm apart. They were asked to maintain a stable posture while fixing a reference point located at eye level (3 m front of them). The arms were held alongside the body. Subjects performed two trials with eyes open and two trials with eyes closed and the trial with less postural sway in both case was used for further analysis. All trials lasted 30 s and were initiated with eyes open. Postural sway during standing was assessed by average absolute deviation of vertical ground reaction force (GRF) during 30-s standing.

Gait analysis

The temporal and spatial characteristics of gait were assessed using 3-D optoelectronic movement analysis system ELITE (BTS Bioengineering, Milan, Italy). Six infrared cameras registered the displacement of 20 reflective markers fixed on anatomical landmarks of the subject regarding to the Davies protocol. Subjects performed three trials of gait on 6-m walkway (Kistler, Switzerland) with freely elected speed, whereas the values of these trials were averaged. The following parameters were calculated: stride length, cadence and mean velocity of gait.

Statistics

Data are means and standard errors (±SE). One-way analysis of variance (ANOVA) followed by Scheffe *post hoc* comparisons was used to test differences between groups and between trials. Spearman correlation coefficients were calculated to assess the relationship motor performance characteristics and scores of UPDRS. A level of $p<0.05$ was selected to indicate statistical significance.

RESULTS

No significant differences in postural sway were observed in PD patients and controls (Fig. 1A). MVC force of the KE muscles (Fig. 1B) did not differ significantly in measured groups, whereas RFD was lower ($p < 0.05$) in PD patients compared with controls (Fig. 1C). Patients with PD had a significantly ($p < 0.05$) shorter step length during gait (Fig. 2A) and mean velocity of gait (Fig. 2B) compared with controls. There were no significant differences in cadence during gait between the measured groups.

The results of correlation analysis in PD patients are presented in Table 1. Significant ($p < 0.01$) negative correlations were observed between UPDRS total score, MVC force and RFD of the KE muscles, and stride length during gait and mean velocity of gait. UPDRS motor score demonstrated a significant ($p < 0.05$) negative correlations with MVC force of the KE muscles and stride length during gait.

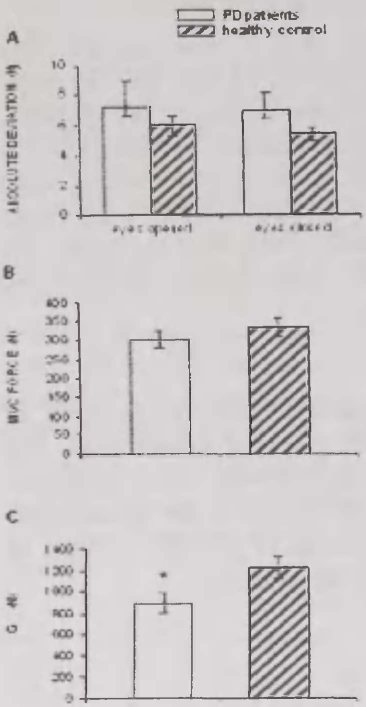

Figure 1. Indicator of postural sway during standing (A), isometric maximal voluntary contraction (MVC) force (B) and rate of force development (RFD) (C) in patients with Parkinson's disease (PD) and nondisabled controls (mean ± SE). * $p < 0.05$ compared with controls.

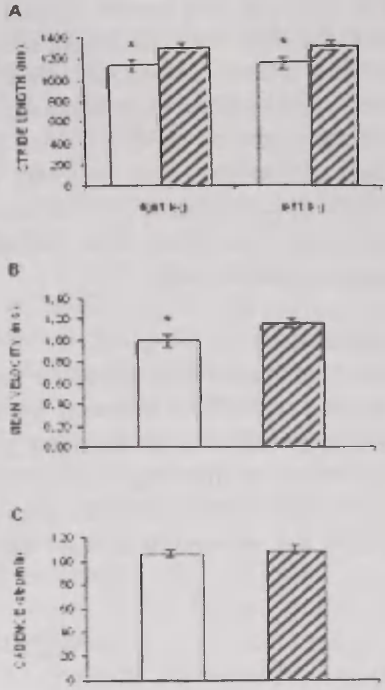

Figure 2. Stride length (A) and cadence (B) during gait, and mean velocity of gait (C) in patients with Parkinson's disease (PD) and nondisabled controls (mean ± SE). * $p < 0.05$ compared with controls.

Table 1. Correlation coefficients between age of subjects, motor performance parameters and Unified Parkinson Disease Rating Scale (UPDRS) scores in patients (n=12)

	$UPDRS_{TOT}$	$UPDRS_{MOT}$
Age	0.50	0.56
Postural instability (standing eyes open)	0.50	0.29
Postural instability (standing eyes open)	0.50	0.44
MVC force of KE muscles	–0.76 **	–0.57 *
RFD of KE muscles	–0.76 **	–0.46
Cadence during gait	0.04	0.09
Stride length during gait	–0.74 **	–0.57 *
Mean velocity of gait	–0.69 **	–0.46

MVC – isometric maximal voluntary contraction, KE – knee extensor muscles, RFD – rate of force development, TOT – total score, MOT – motor score
* $p < 0.05$;
** $p < 0.01$.

DISCUSSION

In agreement with several previous findings the results of this study showed that motor performance of PD patients was lowered compared with age- and gender-matched healthy controls. Although in this study there were no statistically significant differences in standing stability for both the eyes opened and eyes closed conditions, the balance was more impaired in subjects with PD. The postural sway parameter in PD patients was by 22 and 29% greater during standing with eyes opened and eyes closed condition, respectively compared with control subjects. Dietz [2] had proposed that patients with PD rely extensively on vision and flexor muscle control for balance control during stance and locomotion. They hypothesized that extensor load receptors act as body graviceptors and are mainly related to balance on the basis of a ground reference frame. They propose that in PD patients these receptors are poorly functioning, leaving the patient dependent on vision. Lord and Menz [9] have found that in addition to visual information, the KE muscle strength and motor reaction time is also important in retaining postural stability. The loss of KE muscle strength and prolonged reaction time are also related to the postural instability and altered gait parameters. Therefore, postural instability compromises the ability to maintain balance during everyday tasks such as walking, turning and standing up [12]. Higher postural instability in PD patients may also be induced by anti-parkinson medication [17]. Recent studies have shown that isometric muscle strength in PD patients is reduced [14, 21]. The latter may be an expression of general bradykinesia, which is a very common motor sign for PD patients. In our study, MVC force of the KE muscles did not differ significantly in patients with PD and healthy controls. However, the RFD of the KE muscles at 0.2 s after initiation of isometric force during MVC was significantly lower in PD patients than healthy controls. This is in consistent with Stelmach and Worringham [20]. In agreement with previous studies [1, 10], this study demonstrated that subjects with mild-to-moderate PD walk more slowly, with shorter stride length and relatively normal cadence at a comfortable walking speed than age-matched control subjects. PD patients demonstrated by 12% smaller stride length and mean velocity than healthy controls, whereas cadence was similar in PD patients and controls. The basal ganglia play important role in controlling skilled actions that have been practiced to the stage where they can be performed quickly and easily, with little thought [19]. When the basal ganglia are dysfunctional, as in PD, skilled movements are performed more slowly and with smaller amplitude than usual [6].

Former studies have sometimes found more remarkable differences between patients with PD and healthy controls. It has been found that by deliberately focusing their attention to the task that is being performed, PD patients are able to increase their movement speed and amplitude to normal values [13]. This might also be the case in our study. It can be suggested that as a compensation, patients rely more heavily on frontal cortical regions and „on-line" visual, proprioceptive, and auditory input to consciously control and guide movements, and bypass the defective basal ganglia [11, 13].

UPDRS consists of 42 items, each of which is scored from 0 (normal) to 4 (severe), and has been found to demonstrate high internal consistency and inter-rater reliability [15]. Correlation analysis using Spearman correlation coefficients indicated that objective motor performance measures can generally be better described by

UPDRS total score than by UPDRS motor score. The latter can probably be explained when examining the structure of UPDRS test – there are subtests that evaluate motor performance also in other parts of the test besides Motor section. The Motor Examination section of the UPDRS consists of 27 items and it also assesses motor signs that were not assessed in the present study (rigidity, tremor). Also in Motor Examination section various motor signs are not assessed with equal relative importance, for example, items measuring bradykinesia and hypokinesia make up almost 40% of the entire section [15].

We concluded that motor performance in PD patients was lowered and that UPDRS is a tool that enables to measure motor performance in PD patients objectively.

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Correspondence to:
Kadri Noorvee
Institute of Exercise Biology and Physiotherapy
University of Tartu
5 Jakobi Street
51014 Tartu
Estonia

MOOD AND EXPERIENCE AS CORRELATES OF PERFORMANCE IN YOUNG FILIPINO TAEKWONDO ATHLETES

W. Pieter[1], R. S. K. Wong[2], C. Ampongan[3]

[1] School of Health Sciences, Science University of Malaysia, Kubang Kerian, Kelantan, Malaysia

[2] Sport Psychology Unit, National Sports Institute of Malaysia, Sri Petaling, Kuala Lumpur, Malaysia

[3] Physical Education Department, and Athletics Department, Assumption College, Makati, MM, Philippines

ABSTRACT

The purpose of this study was to assess to what extent mood states and experience can be used to predict performance in taekwondo. Subjects consisted of Filipino young beginning taekwondo athletes (123 males, 15.15 ± 0.97 years and 88 females, 13.99 ± 1.28 years), who competed in the National Age Group Championship. The athletes were further subdivided into winners (first – third place finishers) and losers. The Brunel Mood Scale (BRUMS) was administered on the day of competition. Stepwise discriminant analysis was employed to categorize winners and losers by gender based on experience and mood states. In the boys, 55.6% were correctly classified as winners and 64.9% as losers (canonical $R = 0.270$, $Chi^2_2 = 8.929$, $p = 0.012$). The correlation matrix between the discriminant function and the predictor variables showed that taekwondo experience ($r = 0.71$) and anger ($r = 0.67$) were most influential in distinguishing between winners and losers. In the girls, 60.0% were correctly classified as winners and 78.7% as losers (canonical $R = 0.419$, $Chi^2_2 = 16.215$, $p < 0.001$). The predictors related to the discriminant function showed that competition experience ($r = 0.86$) and anger ($r = 0.44$) were most influential in distinguishing between winners and losers. Anger may have been used by the winners to psych themselves up. The relationship between mood and performance in taekwondo may be mediated by experience.

Key words: mood, performance, taekwondo

INTRODUCTION

Early research on psychological mood and performance seemed to suggest that athletes show the so-called iceberg profile when compared to the general population [5]. In other words, athletes score higher than the population 50th percentile on vigor and lower on the negative mood states of tension, depression, anger, confusion and fatigue. It was also suggested that athletes with a positive mental health profile would be more successful [6]. However, later research showed that methodological problems may have obscured the true relationship between mood and sport performance [10, 13]. For instance, mood profile may only distinguish between athletes and non-athletes rather than between athletes of different ability [10]. In a meta-analysis, Rowley et al. [11] reported that the overall effect size for the predictive value of psychological mood in relation to performance was about 0.15, which translated to variance accounted for of less than 1%. However, this does not mean that mood cannot be useful in monitoring an athlete's mind-set, overtraining or performance [13].

Research on mood in martial arts athletes is scarce and most has been done on adults. McGowan and Miller [2] compared karate semifinalists with those placed lower in fighting and forms (sets of pre-determined movements in different directions) using the Profile of Mood States (POMS) [4]. The authors found no difference in any of the mood subscales. When year-long competitions were taken into account, however, the successful competitors scored higher on anger. It was hypothesized that the successful *karateka* (karate athletes) used angry imagery to 'psych' themselves up for competition.

The same pattern was found in experienced *karateka* with first degree black belts scoring higher on anger than their higher ranked colleagues [3], suggesting a possible mediating effect of experience. The investigators proposed that higher ranked black belts may be more self-confident, so they may not need to use anger as a coping mechanism.

Terry and Slade [15] showed that 92% of male *karateka* could be correctly classified as winners or losers based on their profiles of mood states. Confusion, depression, tension and fatigue were especially important in distinguishing between winners and losers.

Pieter et al. [8] found that in male Filipino varsity taekwondo athletes, 78.6% were correctly classified as winners and 66.7% as losers, but this was not statistically significant. Depression and fatigue were most influential in distinguishing between winners and losers. In the women, 80% were correctly classified as winners and 73.9% as losers, but this was also not statistically significant. None of the mood predictors in this case was significantly related to the discriminant function. It is suggested that the statistically non-significant results may be due to the small sample size (38 men and 38 women).

No information is available on mood in young taekwondo athletes. The purpose of this study, then, was to assess to what extent psychological mood, taekwondo and competition experience could correctly classify winners and losers by gender in young taekwondo athletes (*taekwondo-in*).

MATERIALS AND METHODS

Subjects (123 males, 15.15 ± 0.97 years and 88 females, 13.99 ± 1.28 years) participated in the National Age Group Taekwondo Championship in Metro Manila, Philippines. The Brunel Mood Scale (BRUMS) [14] was administered 1 hour before competition. The BRUMS is a 24-item questionnaire consisting of six subscales: Tension, Depression, Anger, Vigor, Fatigue and Confusion. The *taekwondo-in* ranked each descriptor on a 5-point Likert-type scale using the response set "How are you feeling right now?" format. The competitors were divided into winners (those placing first, second and third) and losers as was done in previous research [15].

To determine the differences in taekwondo experience, competition experience and pre-competition mood states between winning and losing *taekwondo-in* within gender, a one-way MANOVA was used. Stepwise discriminant analysis was employed to classify winners and losers within gender using experience and the POMS subscales as predictors. The level of significance for the MANOVAs was set to 0.05. The stepwise discriminant analysis was performed using the F-values of the MANOVAs. To account for the influence of mood over and above that of experience, taekwondo and competition experience were entered first, followed by the mood subscales.

RESULTS

Table 1 shows the vital statistics of the young *taekwondo-in*. Tables 2 (males) and 3 (females) display the differences in mood states between winners and losers. In the boys, the winners had more taekwondo ($p = 0.033$, $eta^2 = 0.038$) and competition experience ($p = 0.033$, $eta^2 = 0.038$). When taekwondo and competition experience were used as co-variates, the difference in anger between winners and losers increased slightly (3.52 ± 2.78 versus 2.44 ± 3.01, $p = 0.036$, $eta^2 = 0.037$).

Table 1. Descriptive statistics for demographic information on young Filipino taekwondo athletes.

	Boys		Girls	
	Winners	Losers	Winners	Losers
n	28	95	41	47
Age (years)	15.27 ± 1.12	15.11 ± 0.93	14.00 ± 1.27	13.98 ± 1.31
Taekwondo experience (yrs)	1.58 ± 0.74	1.30 ± 0.55	1.58 ± 0.67	1.17 ± 0.43
Competition experience (yrs)	1.08 ± 0.74	0.80 ± 0.55	1.10 ± 0.67	0.66 ± 0.43

Table 2. Comparison of pre-competition mood in young male Filipino taekwondo athletes.

Variable	Winners	Losers	p	eta^2
Tension	5.18 ± 2.67	5.77 ± 3.01	0.479	0.004
Depression	3.39 ± 3.33	2.99 ± 2.55	0.473	0.004
Anger	3.43 ± 2.78	2.43 ± 2.30	0.043	0.034
Vigor	9.00 ± 3.30	9.21 ± 3.30	0.917	< 0.001
Fatigue	4.39 ± 3.10	3.92 ± 2.59	0.360	0.007
Confusion	4.50 ± 3.12	4.23 ± 2.56	0.536	0.003

Table 3. Comparison of pre-competition mood in young female Filipino taekwondo athletes.

Variable	Winners	Losers	p	eta^2
Tension	6.88 ± 3.11	5.60 ± 3.25	0.077	0.036
Depression	3.85 ± 3.00	3.15 ± 3.00	0.266	0.015
Anger	3.32 ± 2.78	2.43 ± 2.05	0.063	0.040
Vigor	9.27 ± 2.94	8.70 ± 3.09	0.312	0.012
Fatigue	4.80 ± 3.04	3.85 ± 2.23	0.135	0.026
Confusion	5.00 ± 2.68	4.36 ± 2.58	0.303	0.013

In the girls, the winners also had more taekwondo ($p = 0.001$, $eta^2 = 0.129$) and competition experience ($p < 0.001$, $eta^2 = 0.137$). When taekwondo and competition experience were statistically controlled, the winners scored higher on tension (7.00 ± 3.36 versus 5.48 ± 3.33, $p = 0.049$, $eta^2 = 0.046$) as well as anger (3.50 ± 2.52 versus 2.34 ± 2.50, $p = 0.042$, $eta^2 = 0.049$).

In the boys, taekwondo experience ($r = 0.71$) and anger ($r = 0.67$) were used in the discriminant analysis (Wilks' lambda = 0.927, $F_{1,118} = 4.638$, Eigenvalue = 0.079, canonical $R = 0.270$, $Chi^2_2 = 8.929$, $p = 0.012$). They predicted 55.6% of the winners and 64.9% of the losers for a total of 62.8% correctly classified.

In the girls, competition experience ($r = 0.86$) and anger ($r = 0.44$) were most influential in distinguishing between winners and losers (Wilks' lambda = 0.824, $F_{1,84} = 8.943$, Eigenvalue = 0.213, canonical $R = 0.419$, $Chi^2_2 = 16.215$, $p < 0.001$). They predicted 60.0% of the winners and 78.7% of the losers for a total of 70.1% correctly classified.

DISCUSSION

The difference in mood profile between successful and less successful boy and girl taekwondo athletes was minimal as evidenced by the respective effect sizes, which were less than what was reported by Rowley et al. [11]. When experience was not controlled, the effect of mood on performance was masked, which may have happened in previous research. For instance, the less successful Filipino varsity athletes investigated by Pieter et al. [8] had less experience than their more successful counterparts [7]. It may very well have been that had experience been controlled in the study by Pieter et al. [8], the relationship between psychological mood and performance would have been more in the expected direction.

Experience may be hypothesized to play a role in the way successful and less successful taekwondo-in perceive their opponents. It may be that less experienced taekwondo athletes perceive their opponents as more difficult to beat. Coker and Mickle [1] found less successful female softball players to show a different mood profile depending on how easy or difficult to beat they perceived their opponents to be. Those who were less successful scored higher on tension, anger, confusion and depression, and did not show the iceberg profile. For the present investigation, this implies that pre-competition perception of how difficult it is to beat the opponent may have had an effect on mood that subsequently led to the relationship between mood and taekwondo performance. For instance, Prapavessis et al. [9] suggested that those who are ranked higher or who are already assured of selection in the team produced a different mood profile from those who have not yet been selected.

Interestingly, the winning taekwondo boys and girls in the current study scored higher on anger and tension than their less successful colleagues when experience was controlled. It may be that heightened anger in certain sports has a positive effect on performance as was also found by others [e.g., 3, 12, 15]. In other words, anger did not have a debilitating effect on performance in taekwondo and karate as it was found to have in other sports [1].

Terry and Slade [15] suggested that one particular POMS item referring to anger may have a different meaning for those in combat sports, where being "ready to fight" may be taken literally. However, the authors used the original POMS questionnaire [4] as opposed to the one used for the present study, which does not contain the "ready to fight" item. Nevertheless, it may be that even without that specific item, successful karate and taekwondo athletes use the anger items of the POMS to psych themselves up [e.g., 2]. Ruiz Cerezo [12] suggested that successful elite *karateka* use anger to generate energy and enhanced effort.

Figures 1 and 2 show the mood profiles of the boys and girls, respectively. It clearly can be seen that neither the boys nor the girls showed the iceberg profile as suggested by Morgan [5]. Others also failed to find the iceberg profile in swimmers [9] and softball players

[1]. However, it should be noted that the previous investigators used the original norms from McNair et al. [4] as opposed to ours, which were based on a sports sample [14]. The norms provided by McNair et al. [4] are based on the general population, i.e., non-athletes. Renger [10] suggested that the iceberg profile becomes apparent when athletes are compared to non-athletes. In other words, if the norms based on non-athletes had been used in our study, the adolescent taekwondo athletes may have shown the iceberg profile.

In conclusion, the effect of psychological mood on taekwondo performance in young athletes may be masked by taekwondo and competition experience. Since the effect size of pre-competition mood on taekwondo performance was rather small, even when controlled for experience, future research may want to adopt a multi-factorial model to elucidate the relationship between pre-competition correlates and taekwondo performance.

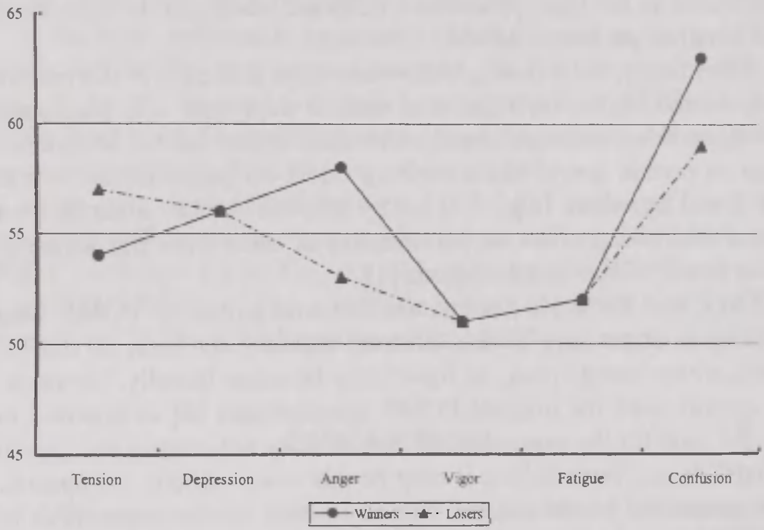

Figure 1. Mood profiles of young Filipino male taekwondo athletes.

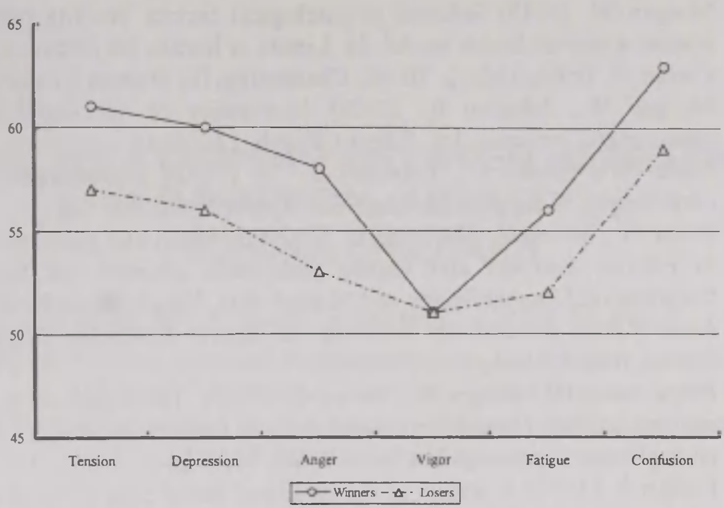

Figure 2. Mood profiles of young Filipino female taekwondo athletes.

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

THE RELATIONSHIP BETWEEN HEADACHE AND PHYSICAL ACTIVITY IN SCHOOLCHILDREN

G. Stratton[1], S. Ryan[2], S. Sartain[3], J. Hill[2], M. Peak[2]

[1] REACH Group, Research Institute for Sports and Exercise Sciences, Liverpool John Moores University, United Kingdom

[2] Liverpool University, Royal Liverpool Children's NHS Trust, Alder Hey, Liverpool, United Kingdom

ABSTRACT

The rationale of this study was first to establish the degree of association between headache and physical activity in children who reported headache and second, to assess whether those children who reported headache were less active then those who did not. If a both hypotheses were supported then it may be possible to lower the burden of headache with interventions that increase physical activity. This approach is also attractive because it does not involve the use of pharmaceutical agents to prevent symptoms and it addresses psychological issues indirectly. 954 questionnaires were distributed to the school for the pupils aged 11–16 and 253 secondary school children and 219 parents returned completed forms. The relationship between physical activity and fitness found in adults was not overtly evident in adolescents this study. There were no differences in physical activity between those who suffered from headache and those that did not. Although a limited correlation coefficient existed between total annual leisure activity and headache frequency this only accounted for 3 per cent of the variance in headache.

Key words: headache, physical activity, schoolchildren

INTRODUCTION

Headaches are common in childhood and a significant cause of morbidity, missing school and other active pursuits [7]. The most recent large-scale British study revealed that around 11% of 5–15 year old school children experienced migraine and two-thirds reported at least one headache episode in the last year. Up to eighty per cent of young people aged 12–15 suffer from headaches with 20 per cent of cases unable to follow normal daily activity [2]. Mortimer found that between 20% and 33% of primary school children had a headache in the previous month [15]. Children with migraine headaches lose an average of 3 days at school each year and they lose further days to other ailments, suggesting co-morbidity with migraine. At the extreme some children may miss up to one third of the school year due to this ailment [2].

In adults headaches have been linked to reduced physical activity although classically exercise has been identified as a trigger for migraine [23]. Recently observations have shown a different relationship between headache and physical activity. Rasmussen showed that adult males who were very sedentary were more likely to get tension headaches [18]. Neususs also found that adults with reduced aerobic power and women with higher levels of adiposity reported higher levels of chronic headache [16].

Furthermore in adults training has been shown to reduce the prevalence of headache. Aerobic exercise training resulted in reduced headache activity in subjects with vascular headache [5]. Two investigations have revealed that 6-weeks of aerobic exercise caused an increase in physical fitness and a decrease in number of migraine attacks and headache pain severity, reduced headache frequency and duration after training [11, 14]. Increases in beta endorphins were also elevated after the exercise programme [11]. These results suggested that aerobic fitness programmes could be used in the management of classical migraines. Few studies have examined the effect of resistance exercise on headache although a programme of isotonic exercise combined with posture education including massage and stretching resulted in a reduction in the frequency of tension-type headache in adults [8].

There is some evidence to suggest that structured exercise programmes may ameliorate headache symptoms in adults. The relationship between fitness or physical activity and headache has not been reported in children. Given the impact of headache on children's lifestyle studies that investigate the link between headache and physical activity and fitness in children and adolescents are required. With these hypotheses in mind this study set out to explore the relationship between headache and physical activity.

The rationale of this study was first to establish the degree of association between headache and physical activity in children who reported headache and second, to assess whether those children who reported headache were less active then those who did not. If a both hypotheses were supported then it may be possible to lower the burden of headache with interventions that increase physical activity. This approach is also attractive because it does not involve the use of pharmaceutical agents to prevent symptoms and it addresses psychological issues indirectly.

METHODS AND PARTICIPANTS

Study design

A pilot cross-sectional questionnaire based study to child-parent pairs. The present report deals with the schoolchildren's questionnaires.

Setting

A single, mainstream, mixed secondary school in the United Kingdom.

Participants

954 questionnaires were distributed to the school for the pupils aged 11–16 and 253 secondary school children and 219 parents returned completed forms.

Method

Form tutors at the school received paired questionnaires corresponding to the number of pupils in their form. A teacher from the school was identified to administer the questionnaires to the form tutors.

Each child was given an envelope at school to be taken home to their parent(s). It contained an information document, a consent form and a questionnaire. The (sealed) envelope was returned with the child to school the next day and if the parent agreed the child was then issued with a similar envelope containing the information, consent form and questionnaire for young people. The questionnaires were completed during class time and envelopes were returned to form tutors and collected at the school by the researcher. No individual identification was sought but a code number was used to allow parents and children's questionnaires to be matched. Each questionnaire contained 3 components; the Modifiable Activity Questionnaire [1] and the Strengths and Difficulties Questionnaire [6] and the headache questionnaire [10, 17, 20]. The Modifiable Activity Questionnaire for Adolescents (MAQA) is a reliable and validated tool, which can be used in the general population [1]. The MAQA provides information on the number of activities young people pursued over of the previous 12 months by identifying activities and the frequency of each activity in months per year, days per week and minutes each day. Thus total year leisure activity in hours per week for each participant can be estimated. It was also possible to investigate more vigorous "hard" physical exercise by recording the frequency of episodes of twenty-or-more-minutes of vigorous exercise over the previous 14 days. Less vigorous "light" activity was also identified. Sedentary activity such as watching TV or videos over a normal week was also recorded.

The second component, the strengths and difficulties questionnaire [6] consisted of five scales, each containing five items. The five, 5-item scales pertain to emotional symptoms, conduct problems, hyperactivity, peer problems and a pro-social scale. A total strengths and difficulties score was obtained by summing 4 of these scales, excluding the pro-social scale. Pupils were ranked as normal, borderline or abnormal, depending on the scores. A 'normal' score ranges from 1 to 15, a 'borderline' score from 16 to 19 and 'abnormal' score from 20–40. Approximately 10% of a community sample scores in the abnormal band on any given scale, with a further 10% scoring in the borderline band.

A prospective headache questionnaire designed for the study based on work by Hershey and colleagues [10], Viswanath and colleagues [20] and the International Headache Society (IHS) classification index [17]. The questionnaire has several domains; presence of headaches, frequency, duration, severity and disability; triggers, associated symptoms, treatment and its effect, family history.

The primary outcome measured was whether there was a relationship between physical activity score and headache. This was established by analysing the relationship between the main output of the Modifiable Activity Questionnaire (total year leisure activity reported as hours per week) and headache frequency, duration and severity independently. All other analyses were pre-planned but secondary and included using a headache score (the frequency, duration and severity components multiplied to give measure of headache density). The relationship between hard exercise, sedentary activity and headache and between headache and the components of the Strength and Difficulties Questionnaire were also examined. All relationships were analysed using a Spearman rho. Differences in physical activity between those who reported headache and those that did not were analysed using a Mann Whitney U test. Significance was set at $p < 0.05$. All analyses were carried out using SPSS (v10.0).

The study was authorised by the Research Review Committee of Royal Liverpool Children's National Health Service Trust and was approved by the Liverpool Health Authority Research Ethics Committee. All parents and pupils in the school study gave written informed consent and in the clinic all parents and competent children gave written informed consent.

Table 1. shows the rate of completion for the questionnaires that were returned. One hundred and seven males (42%) and 146 (58%) females completed the questionnaire. Pupils ranged in age from 11 to 16 years, with a median age of 13. The overall return rate of 27% was disappointing but may be attributed to current time pressures on schoolteachers and administrators. Questionnaires took 15 to 20 minutes to complete.

Table 1. Completion rate for the items on the questionnaire: list of main items for analysis.

Item	no. completed (%)	no. missing (%)
Headache Questionnaire		
Headache yes/no	240 (94.5%)	13 (5%)
Headache frequency	155 (98.7%)	2 (1.3%)
Headache duration	154 (98.1%)	3 (1.9%)
Headache severity	155 (98.7%)	2 (1.3%)
Modifiable Activity Questionnaire		
Total leisure activity in hrs/week	238 (94.1%)	15 (5.9%)
Frequency of hard exercise	248 (98%)	5 (2%)
Frequency of light exercise	250 (98.8%)	3 (1.2%)
Hours per day TV/videos	247 (97.6%)	6 (2.4%)
Strengths and Difficulties Questionnaire		
Overall score for strengths and difficulties	227 (89.7%)	26 (10.3%)
Emotional symptoms scale	235 (92.9%)	18 (7.1%)
Conduct problems scale	236 (93.3%)	17 (6.7%)
Hyperactivity scale	237 (93.7%)	16 (6.3%)
Peer problems scale	237 (93.7%)	16 (6.3%)
Prosocial scale	235 (92.9%)	18 (7.1%)

For the first item on the headache questionnaire 'do you get headaches', 157 pupils answered 'yes'. This gives a rate of prevalence of 65% for headache among those who participated in the pilot study. Seventy percent of girls and 59% of boys who responded reported headaches. Headache frequency ranged from 'every day' to 'some months' but the median frequency recorded as 'every fortnight' (Figure 1).

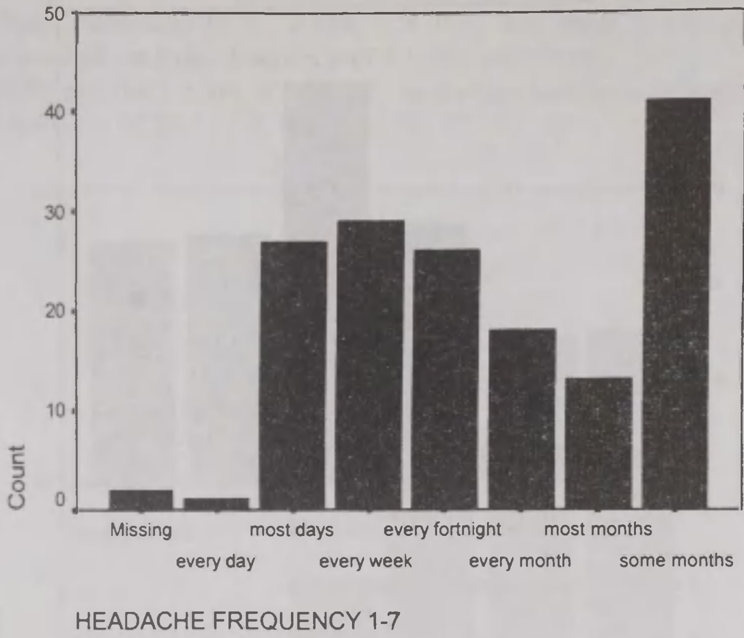

Figure 1. Headache frequency in adolescents.

Headache Frequency in Secondary age Schoolchildren

Headache duration ranged from '1 to 5 minutes' to '24 hours or more' with a median value of '31 to 60 minutes.' Headache severity was reported for the last headache, on a scale of 1 to 10. A median score of 4 was obtained with the range. Girls reported both longer duration (median 6 to 30 minutes versus 1 to 5 minutes; $z = -2.55$, $p = 0.01$) and more severe (median score 4/10 versus 3/10; $Z = -2.36$, $p = 0.019$) compared to boys.

MAQA data in total year leisure activity in hours per week for each participant revealed a median amount of weekly leisure activity was 3.8 hours per week. The frequency of 20 or-more-minutes of hard exercise over 14 days ranged from 'no days' to '9 or more days'. The median score was '3 to 5' days. Subjects engaged in moderate exercise more frequently than hard exercise, giving a median value of '6 to 8 days' in the past 14 days.

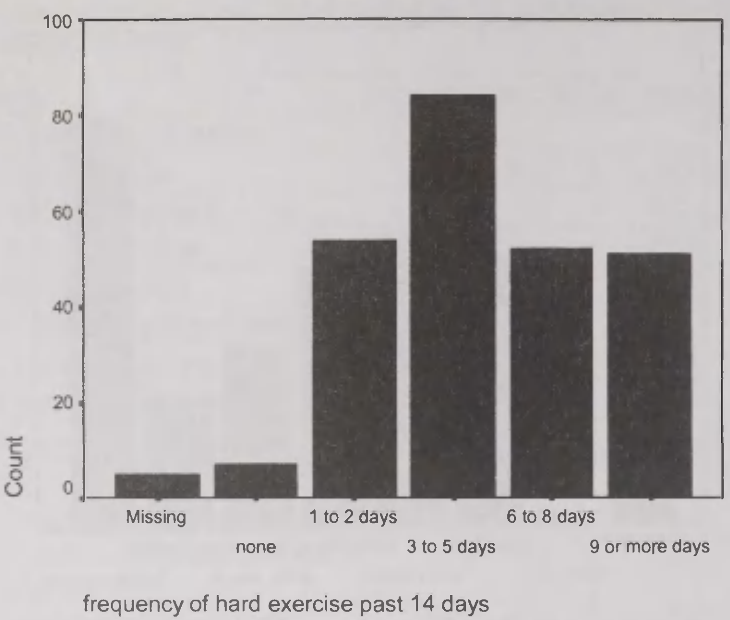

Figure 2. Frequency of hard physical exercise over the previous 2 weeks

Frequency of hard physical exercise

Sedentary activity over a normal week was also recorded. Responses ranged from 'no hours' to '6 or more hours' with a median value of '4 to 5 hours' per day watching TV or videos.

Subjects recorded a median score of 9 (range 0 to 29) on the Strengths and Difficulties Questionnaire. Only 9 pupils (3%) had a score of 20 or above, whilst 27 (12%) had borderline scores of 16 to 19. Approximately 10% of a community sample scores in the abnormal band on any given scale, with a further 10% scoring in the borderline band. In the present sample, pupils did not exceed the parameters with scores ranging from 2% to 10% in the borderline band and 6% to 10% in the abnormal band.

Total annual leisure activity had a median value of 3.8 hours per week and there was no significant difference between those children with headaches and those without ($Z = -0.17$, $p = 0.86$). Median hard exercise frequency in the previous 2 weeks was 2.0 hours and once again there was no difference in this parameter in those with an without headaches ($Z = -0.624$, $p = 0.5$). The same was true for median light exercise frequency of 3 hours per 2 weeks ($Z = -0.93$, $p = 0.29$) and the 3 hours of television and video watching each day ($Z = -0.93$, $p = 0.35$).

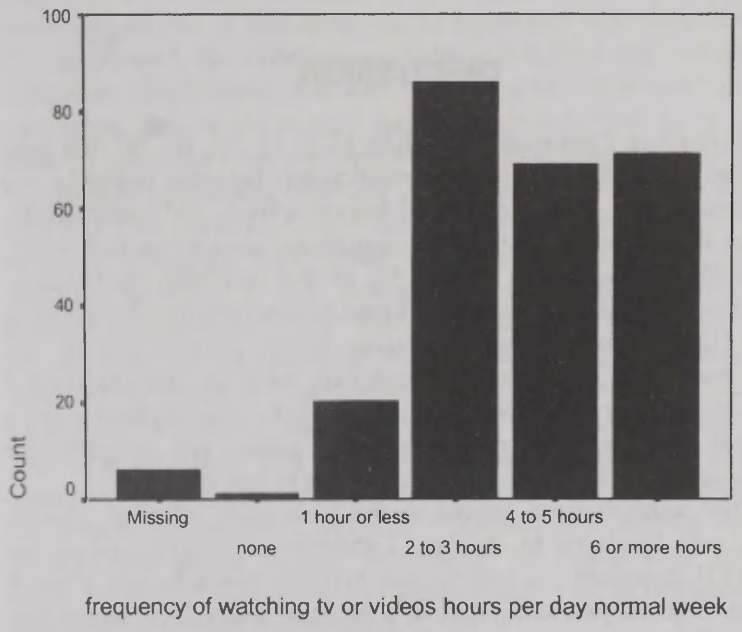

Figure 3. Time spent watching television or videos during a typical week in the school population.

Frequency of time spent watching TV or video

The relationship between measures of headache (frequency, severity, duration and density) and measures of physical activity were then examined by linear regression in those children who reported headache. No significant relationship was demonstrated other than for total annual leisure activity (reported as hours per week) and headache frequency ($r = 0.165$, $p = 0.05$). When these relationships were examined for subjects grouped by sex, no significant associations were demonstrated.

These data provided limited evidence to support the primary hypothesis, that there was a relationship between physical activity and headache in children. There were also no significant differences between those that reported headache and those that did not for any measure of physical activity.

DISCUSSION

Unlike findings from studies in adults [5, 8, 11, 14, 16, 18] data from this study only found a limited relationship between headache and physical activity. The total annual leisure activity and headache frequency demonstrated a small but significant association ($r = -0.17$, $p < 0.05$), equivalent to around 3% of the variability in headache frequency being due to variation in total leisure activity. One previous study [12] of the relationship between leisure physical activity and aches and pains in children showed that, whereas musculo-skeletal pains in children were more frequent in those who undertake more physical activity, non musculoskeletal pains, and in particular headache among boys ($p = 0.004$) tended to be less common.

Other workers have looked at the association of other lifestyle issues with headache in children. Leonardsson-Hellgren and colleagues [13] examined the associations between headache and lifestyle among 13 to 16 year old pupils at a Swedish senior level elementary school. They found that 22% had a headache at least weekly and this was more common among girls than boys. In girls headache was associated with smoking (Odds Ratio; (OR) 6.6), going to bed later than 23:00 hours (OR 4.4) and a lower number of sports activities (OR 3.0; CI 1.2–7.5). The only association in boys was with smoking (OR 12.0). This study very much suggests that lifestyle factors affecting headache and other causes of pain (such as low back pain, [21]) are multi-factorial and that sex differences exist. One issue we did not investigate but which is commonly mentioned at headache clinic is the perceived overuse of computers and games consoles – predominantly for leisure. Any investigation of this area would need to be carefully designed as an increase in computer use and TV watching is negatively associated with reduced physical activity and long-term health [9] and possibly delayed or disturbed sleeping.

Our modest positive finding rather than a more significant relationship could be explained by a real lack of an association between physical activity and headaches in our target population but it could also be due to deficiencies in the planning and conduct of the study. In this respect the biggest issue may have been the very low return rate for the questionnaires. On the other hand, the prevalence of headache reported in this study was in agreement with other UK data [2]. Additionally the distribution of the scores from the strength and difficulties questionnaire was also in keeping with that seen in such a population. This would suggest that although there was a low rate of return of questionnaires, we identified a study group representative of the general population. Perhaps the weaker relationship between headache and physical activity in children compared to adults is a result of relatively high levels of physical activity in children compared to adults or that youngsters overestimate their levels of physical activity in self-report studies. These higher levels of physical activity may also be measured with a greater degree of sensitivity using more objective measurement instruments such as accelerometers, pedometers, or heart rate monitors [22]. These measures are more able to capture the short bursts of activity typically found in youngsters. Objective measures are more effective at differentiating the volume (frequency x duration x intensity) of activity between children and future studies examining the relationship between physical activity and headache in children may wish to consider using objective measurement techniques.

Our findings of associations between the presence of headaches and a higher emotion sub-score and the total strengths and difficulties score echo common clinical understanding and research, behavioural and emotional issues are intertwined with symptoms within the child and within the social framework [4]. Within the group of children with headaches a significant relationship between headache duration and emotion sub-score and total strength and difficulties score was identified. This confirmed the complex interaction between physical activity, mental functioning and symptoms such as headache.

CONCLUSION

The relationship between physical activity and fitness found in adults was not overtly evident in adolescents this study. There were no differences in physical activity between those who suffered from headache and those that did not. Although a limited correlation coefficient existed between total annual leisure activity and headache frequency. This only accounted for 3 per cent of the variance in headache. Finally, a more detailed analysis of headache and its interplay with physical activity and other factors is required and supports currently identified gaps in the literature [3, 19]. This will need multidisciplinary approaches using more sensitive instrumentation to measure physical activity patterns alongside frequency, duration and intensity of headache.

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Correspondence to:
Gareth Stratton
Research into Exercise Activity and Children's Health (REACH) Group
Research Institute for Sports and Exercise Sciences
Liverpool John Moores University
Henry Cotton Campus
15–21 Webster St.
Liverpool
L3 2ET
United Kingdom

THE EFFECT OF TRAINING ON GENERAL MOTOR ABILITIES IN YOUNG MALAYSIAN TAEKWONDO ATHLETES

M. A. Suzana[1], W. Pieter[2]

[1]International Taekwondo Federation of Malaysia, Batu Pahat, Johor, Malaysia

[2]School of Health Sciences, Science University of Malaysia, Kubang Kerian, Kelantan, Malaysia

ABSTRACT

The purpose of this study was to assess the effect of training on general motor abilities in young Malaysian male and female taekwondo athletes. Subjects (9 females, 15.52 ± 1.24 years, 161.33 ± 5.20 cm, 51.67 ± 5.98 kg at the pre-test; 14 males, 16.81 ±1.40 years, 172.07 ± 2.56 cm, 65.71 ± 11.10 kg at the pre-test) were members of the Malaysian national junior taekwondo teams. The athletes worked out 4–5 days/week, 2.5–3 hours/session. The motor abilities tested included sit-and-reach, 30-second sit-ups, maximal push-ups, vertical jump, 6-second dash, static balance and agility. Ratio scale data were analyzed using a 2-way (Gender x Test) ANOVA with repeated measures on the second factor, while non-parametric procedures were used for frequencies. Collapsed over gender, the athletes covered more distance in the 6-sec dash during the pre-test (42.17 ± 4.67 m vs. 38.37 ± 4.79 m, $p < 0.001$, $eta^2 = 0.69$). The boys jumped higher than the girls (56.30 ± 4.89 cm vs. 37.72 ± 6.30 cm, $p < 0.001$, $eta^2 = 0.751$) and did more sit-ups during the post-test (median: 37 vs. 26, $p = 0.002$), but there was no difference in push-ups at the post-test (median: 49 vs. 47, $p > 0.05$). Collapsed over gender, balance improved over time (28.57 ± 25.34 sec vs. 46.82 ± 36.84 sec, $p = 0.005$, $eta^2 = 0.321$). Regardless of gender, general motor abilities improved over time as a result of training.

Key words: motor abilities, taekwondo

INTRODUCTION

In recent years, the interest in the scientific study of taekwondo has increased, especially after the sport's inclusion in the 2000 Olympic Games. Most of this research is on taekwondo as propagated by the World Taekwondo Federation (WTF). For instance, [23] investigated the relationship between experience, gender and cardiovascular and metabolic responses in taekwondo, while a follow-up study focused on the physiological profile of adult recreational taekwondo athletes [22]. Other work reported on injuries [7], competition anxiety [1], and somatotype and body composition [11].

Compared to research on Olympic taekwondo, less is known about taekwondo as practiced by the International Taekwondo Federation (ITF). Early studies focused on aggressive behaviour [19] and personality characteristics [8], while competition orientation was recently investigated [13]. Only one study to date was found examining physiological characteristics of taekwondo athletes associated with the ITF. [5] Profiled the men's and women's Czech national teams and reported that, on average, participants were only active for 17–18% of the total competition time. The authors concluded that, generally, physiological and kinanthropometric qualities do not seem to be highly correlated with performance. The athletes seem to have a high anaerobic endurance, low body fat and well developed flexibility when compared to the general population.

Most research on taekwondo, whether Olympic or otherwise, uses Caucasian subjects. There's a scarcity of studies on Asian samples other than Korean taekwondo athletes [11, 20]. Pieter et al. [16] investigated demographic and kinanthropometric determinants of taekwondo performance in Filipino varsity athletes and found experience and height to be related to winning. No studies are currently available on Malaysian taekwondo participants. The purpose of this study, therefore, was to investigate the effect of a training program on young Malaysian taekwondo athletes in preparation for the Junior ITF World Taekwondo Championship.

METHODS

Subjects (9 females, 15.52 ± 1.24 years, 161.33 ± 5.20 cm, 51.67 ± 5.98 kg and 14 males, 16.81 ± 1.40 years, 172.07 ± 2.56 cm, 65.71 ± 11.10 kg) were members of the national taekwondo teams of the International Taekwondo Federation (ITF) of Malaysia participating in the 6th Junior ITF World Taekwondo Championship. The athletes worked out 4–5 days/week, 2.5–3 hours/session. The intervention program, consisting of general motor ability and taekwondo-specific exercises, was implemented one month prior to the world championship.

In addition to height, measured to the nearest 0.1 cm on a wall-mounted wooden stadiometer and weight, measured to the nearest 0.5 kg on a digital weighing scale (Kubota KA-10-150V, Tokyo, Japan), flexibility of the lower back and hamstrings was assessed through the sit-and-reach test [6, 17]. Two trials were allowed and the highest score used for analysis. Abdominal and upper body strength and endurance were measured by means of the 30-second sit-ups and maximal push-ups tests. The girls performed the modified push-ups. Explosive leg power was assessed using the vertical jump test with the highest score out of two attempts used for statistical analysis, while general speed was determined by the distance covered in 6 seconds of all-out sprinting [6]. The stork stand was used to assess static balance [6].The reciprocal ponderal index (RPI, $cm/kg^{-0.333}$) was utilized as a measure of weight for height.

An independent t-test with the Bonferroni correction was employed to determine the differences in vital statistics between boys and girls at the pre-test. A 2-way (Gender x Test) ANOVA with repeated measures on the second factor was employed to determine the differences in general motor abilities between boys and girls. Frequency data were analyzed using the median test. For non-normal data, even after log transformation, as well as skewed or kurtotic distributions, the L statistic was utilized. Both ratio standard and multivariate allometric scaling were used to control for the effect of body size when comparing male and female athletes. To establish to what extent the scaling method was successful, Pearson correlations were employed. The level of significance for the median test was set at 0.05, while a Bonferroni-corrected alpha was used for the ANOVA.

RESULTS

Table 1 displays the means and standard deviations of the general motor abilities. The boys were older than the girls ($p = 0.035$), but there was no difference in age after the Bonferroni correction ($p = 0.140$). The girls were shorter ($p = 0.001$) and lighter ($p = 0.003$), but there was no difference in RPI (43.46 ± 1.28 cm/kg$^{-0.333}$ versus 42.95 ± 2.51 cm/kg$^{-0.333}$, $p = 0.574$).

Table 1. Descriptive statistics of motor abilities in young male and female taekwondo athletes over time

	Boys (n=14)		Girls (n=9)	
	Pre-test	Post-test	Pre-test	Post-test
Flexibility (cm)	19.93 ± 5.54	24.62 ± 6.10	20.63 ± 4.69	26.11 ± 5.44
Sit-ups (median reps)	30.50	37.00	22.00	26.00
Push-ups (median reps)	37.50	49.00	33.00	47.00
Vertical jump (cm)	56.14 ± 4.99	56.46 ± 5.77	36.11 ± 5.73	39.33 ± 7.31
Speed (m)	45.07 ± 3.17	41.46 ± 3.27	37.67 ± 2.45	33.56 ± 1.67
Balance (sec)	34.86 ± 25.56	51.85 ± 39.31	18.78 ± 22.96	39.00 ± 33.28

Collapsed over gender, the taekwondo athletes improved their flexibility over time (20.20 ± 5.12 cm at the pre-test and 25.20 ± 5.77 cm at the post-test, $p < 0.001$, eta$^2 = 0.617$). They also improved their balance over time: 28.57 ± 25.34 sec versus 46.82 ± 36.84 sec ($p = 0.005$, eta$^2 = 0.321$). However, they were slower at the post-test, covering less distance: 38.37 ± 4.79 m versus 42.17 ± 4.67 m at the pre-test ($p < 0.001$, eta$^2 = 0.687$). The boys were faster than the girls, covering more distance in the same amount of time: 43.27 ± 2.83 m versus 35.61 ± 1.90 m ($p < 0.001$, eta$^2 = 0.707$).

The boys also jumped higher: 56.30 ± 4.89 cm versus 37.72 ± 6.30 cm ($p < 0.001$, eta$^2 = 0.751$). When vertical jump was controlled for ratio standard body mass, the taekwondo athletes collapsed over gender jumped higher at the post-test (0.84 ± 0.20 cm/kg versus $0.82 \pm$

0.20 cm/kg, $p = 0.043$, $eta^2 = 0.181$). However, the effect of the body size variable was not adequately eliminated during the post-test ($r = -0.48$, $p = 0.021$) versus the pre-test ($r = -0.35$, $p = 0.099$).

It was subsequently decided to use multivariate allometric scaling to control for the body size variable with body mass and gender as the predictors. To account for the independent effect of height on the vertical jump, it was used as a co-variate. The boys jumped higher than the girls: 6.32 ± 0.13 cm/kg$^{-0.314}$ versus 5.58 ± 0.25 cm/kg$^{-0.314}$ ($p < 0.001$, $eta^2 = 0.702$). The effect of body mass was adequately controlled when allometrically scaled: $r = -0.42$ ($p = 0.267$) for the girls and $r = -0.41$ ($p = 0.143$) for the boys.

Although the median sit-ups for the boys was higher than that of the girls at the pre-test ($p = 0.009$), there was no difference in the post-test value ($p = 0.089$). Both boys ($p = 0.001$) and girls ($p = 0.003$) improved their sit-ups from pre- to post-test. There were no differences in pre- and post-test median push-ups between boys and girls ($p = 0.228$ each).

DISCUSSION

Even though it is recognized that RPI depends on weight division in weight-categorized sports such as taekwondo [3], weight for height in this sample compares favourably to those reported in the literature for adult taekwondo athletes, as expected. For instance, 23-year (males) and 20-year old Filipino national elite athletes [16] recorded RPI's of 43.13 cm/kg$^{-0.333}$ and 43.03 cm/kg$^{-0.333}$, respectively. Male Korean state and club taekwondo athletes (19.8 years) carried more weight for height: 42.60 cm/kg$^{-0.333}$ and 42.37 cm/kg$^{-0.333}$, respectively [11], than the Malaysian junior athletes. Female Korean college taekwondo athletes (19.1 years) also carried more weight for height: 42.31 cm/kg$^{-0.333}$ [20] as did British female club athletes (24.1 years): 41.72 cm/kg$^{-0.333}$ [3] and Czech female national elite athletes (18.5 years): 42.51 cm/kg$^{-0.333}$ [5]. However, compared to American junior elite taekwondo athletes, the Malaysian counterparts carry more weight for height. The values for the Americans were 44.87 cm/kg$^{-0.333}$ and 44.27 cm/kg$^{-0.333}$, for boys (16.5 years) and girls (15.1 years), respectively [14]. Too much weight for height, especially if the weight consists of fat, will negatively affect the weight-to-strength ratio [18] and, as a result, taekwondo performance [14].

Flexibility is regarded as an important component of fitness in taekwondo [5, 21]. At the post-test, the boys in the current study scored around the 25th percentile of norms for the sit-and-reach for their age group, while the girls scored below the 31st percentile [6]. Compared to the National Children and Youth Fitness Survey (NCYFS) norms, both boys and girls scored around the 10th percentile for their age group at the post-test, while the girls scored below the 10th percentile [17]. Chinese boys of the same age had a sit-and-reach flexibility of 38.01 cm and the Chinese girls of the same age as the Malaysian junior athletes recorded 38.64 cm [4]. Based on the literature, one would have expected higher scores for the junior taekwondo athletes. For instance, American male adult recreational taekwondo athletes recorded 53.2 cm during the sit-and-reach test [21]. On the other hand, the sit-and-reach flexibility of Czech national elite taekwondo athletes was 36.9 cm and 37.9 cm for men and women, respectively, which were 158% (men) and 142% (women) of national norms [5]. Adult college male recreational taekwondo athletes scored 53.4 cm and their female counterparts, 45.0 cm [22]. It is acknowledged that in these comparisons, the effect of the limb proportional differences between the Malaysian junior taekwondo athletes and their Western adult counterparts has been disregarded.

Since the designs of the aforementioned studies preclude any conclusions regarding the effect of taekwondo training on flexibility, further research is warranted to elucidate the relationship between flexibility and taekwondo training. The current study seems to indicate that a 1-month intervention program will lead to moderate improvements in sit-and-reach flexibility in junior taekwondo athletes. Further studies should also attempt to clarify the relationship between flexibility and taekwondo competition performance using a multi-factorial model.

Sit-ups as a component of core stability in the boys at both the pre- and post-test exceeded the 'high score' classification for their age group (27 repetitions or higher) of the Eurofit test battery [24]. The girls scored at the bottom end of the 'high score' category for their age group (22 repetitions) at the pre-test, but higher at the post-test [24]. It is suggested to develop the musculature around the trunk as optimally as possible, since they are involved in punching from various stances in taekwondo or executing such kicks as the roundhouse and spinning hook kicks.

The girls did more push-ups during the post-test than the "excellent" classification (33+) for girls 15–19 years old as did the boys (39+) for the same age group [10]. The means for the girls were 36.22 repetitions and 46.33 repetitions for the pre- and post-test, respectively. For the boys, the values were 39.07 reps and 47.00 reps, respectively. Contrary to their counterparts in the World Taekwondo Federation, the junior athletes in the current study compete in a system where upper limb techniques are awarded points. In other words, well developed upper body strength and endurance will more readily be related to improved taekwondo performance.

Explosive leg power has a bearing on jumping ability in taekwondo and, indirectly, kicking force, in that the initial movement of the vertical jump during the downward phase resembles that of many kicks. The vertical jump of the boys at the pre- and post-tests ranked between the 70th and 80th percentiles for their age group, while that of the girls at the 70th (pre-test) and at the 80th percentiles (post-test) [17]. The boys at both the pre- and post-test jumped higher than American adult male recreational taekwondo athletes (51.5 cm), as did the girls compared to the American females (31.3 cm) [22].

It is not clear why the boys did not improve as much. It may be that they were experiencing a plateau in terms of the effect of their training program on vertical jump height [15], while the girls were still going through a training effect. The gender difference in absolute vertical jump height was moderate to large and may be attributed to a larger muscle cross-sectional area and higher testosterone level in the boys, even at that age. It is not unreasonable to assume that the girls had a higher fat mass, and that their similar weight for height may have been caused by a larger amount of fat [3, 9].

Interestingly, the gender effect disappeared when vertical jump height was controlled for body mass in ratio standard, apparently indicating that the higher body mass of the boys was positively related to their better jump performance. However, the ratio standard did not adequately control for the effect of the body size variable. The test effect for vertical jump height relative to body mass in ratio standard is considered scientifically trivial.

When vertical jump height was allometrically scaled for body mass and height used as a co-variate, the boys again jumped higher and the effect was moderate to high. Multivariate scaling adequately controlled for the effect of body mass. In other words, even when controlled for the effects of body mass and height, the boys still jumped higher. Future research should consider using other variables in their scaling approach in addition to the ones mentioned here. For instance, isokinetic leg strength and leg volume could be used.

At the pre-test, both the boy and girl taekwondo athletes scored at the top end of the 'good' range of norms for secondary schoolboys and -girls for general speed [6]. However, at the post-test, both dropped to the 'average' range of norms [6]. It is not surprising that the taekwondo athletes decreased in general speed over time. Their training had become more specific in preparation for the upcoming competition that was held some 10 days after the post-test, so that more emphasis was put on taekwondo-specific speed [15].

Compared to published norms for college students, the boy taekwondo athletes at the post-test scored around the lower cut-off point of the advanced category (51 seconds) for static balance, while the girls at the post-test far exceeded the lower cut-point (28 seconds) of their advanced category [6]. The superior balance skills of athletes compared to the general population is expected [17]. Although static balance is more appropriate to assess the maturity of the neuromuscular system of subjects younger than those investigated in the current study [2], it served as an initial measure of establishing baseline data for future assessments. If it is known how junior taekwondo athletes score on static balance, any future talent identification program will have a goal with which to compare its test results, especially since the age at which children start their first taekwondo training is as young as 5 years old [12].

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

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ARE SWIMMING CHAMPIONS THAT SPECIAL? PSYCHO/SOCIAL COMPARISONS WITH OTHER FINALISTS

N. O. Vikander[1], R. K. Stallman[2]

[1]Nord-Trøndelag University College, Levanger, Norway
[2]Norwegian School of Sport Sciences, Oslo, Norway

ABSTRACT

Anthropometric, physiological, and biomechanical distinctions between swimming champions and those who do not quite reach the top of the podium, are well researched in swimming science. However, divergencies in psycho/social characteristics are less well mapped out despite the prospects of interventions in this area with performance-enhancing objectives being more rewarding in terms of time/energy-cost analyses. In the present study, The Psychological Inventories for Competitive Swimmers (PICS) were administered to 18 Norwegian national senior individual champions (9 women and 9 men) and 19 finalists (8 women and 11 men) who did not achieve victory at national championships in their careers. Forty-two (42) items of the 242-unit PICS were responded to in a like manner by a minimum of 75% of each of the two sub-samples, and met the criterion of well-anchored characteristics. These were examined for clustering tendencies, and were distributed in the following 7 theme areas: General Features (6), Relationship with Coach (6), Relationship with Swimmers (5), Training (4), Pre-Competition (5), Competition (5), Motivational Features (11). Items were listed as specific to champions, specific to other finalists, or common to both. Developmental implications are discussed for both swimmer and coach in terms of the specific features. Primary purpose of the inquiry is to stimulate the recognition and implementation of the psycho/social elements in the aquatic performance equation, based on the generally positive modelling impact of champions. As an investigative tool for swimmer and coach development, the procedure lends itself well to longitudinal application.

Key words: champion "model" features, performance enhancement, pedagogy

INTRODUCTION

Anthropometric, physiological, and biomechanical distinctions between champions and those who do not reach the top of the podium are increasingly well researched in swimming science [1]. Divergencies in psycho/social characteristics are, however, less thoroughly investigated despite the potential that interventions aiming at performance enhancement in this arena would be more advantageous in terms of time and energy-cost analyses. The rationale of the present study was to examine whether such distinctions exist and, if found, to assess their implications for swimmer development and coaching practice. Fundamental to the latter is the view that characteristics distinguishing champions are with strong likelihood performance-enhancing, and thus worthy of serious consideration in the developing swimmer's repertoire.

MATERIALS AND METHODS

The Psychological Inventories for Competitive Swimmers (PICS) (242 items) developed by Rushall [11] were administered to 18 individual Norwegian National Senior Swimming Champions (9 women and 9 men), and to 19 swimmers (8 women and 11 men) who in their careers reached finals but did not achieve victory. The methodology [10] of requiring a minimum of 75% commonality in PICS item response was the criterion for indicating deeply anchored characteristics, and thus determining inclusion in the analysis. In this investigation, consequently, 14 of the 18 champions (77.8%) had to answer similarly for an item to merit inclusion, whereas 15 of the 19 finalists (78.9%) had to agree. The resulting items were assessed for clustering tendencies, and were listed as specific to champions, specific to non-winning finalists, or as common to both. Items in the specific categories were evaluated for their performance-enhancing/ diminishing potentialities and assessed also from the perspective of coaching practice. The remaining features, those common to both sub-samples, are presented in the results but are not commented upon.

RESULTS

Forty-two (42) items met the criterion for inclusion, and were found in the 3 categories as follows:
A) 20 champion-specific items
B) 21 item common to champions and other finalists
C) 1 item specific to non-winning finalists
The clustering assessment resulted in 7 theme areas with a distribution of the 42 items as follows:

I. General Features:
Champions: –
I consider that swimming is the most important activity that I do.
My spirits generally stay high no matter how many troubles I meet in my swimming.
If something badly upsets me about my swimming, I generally calm down again quite quickly.
I have always been free from vague feelings of ill-health, such as obscure pains, digestive upsets, awareness of heart action, etc., during training and competition.
Champions and other Finalists: –
I strive for better swimming performances.
Slow motion videos or movies always give me more understanding about my swimming.

II. Relationship with Coach:
Champions: –
I would like to make decisions about my swimming training, techniques, and racing with my coach.
Champions and other Finalists: –

When a coach tells me to do something, I like to know the reasons behind it.
I like the coach to comment frequently on my techniques.
I would like the coach to tell me that he/she likes the way that I am training or performing.
When the coach asks me about my swimming training or races, I always tell the truth.
Non-Winning Finalists: –
I learn things about swimming best when they are explained by a coach.

III. Relationship with Swimmers:
Champions: –
I occasionally feel grouchy and do not want to work with other swimmers.
I never consider that the results of my swimming races are more important for the team than they are for me.
Champions and other Finalists: –
One of the enjoyable things about competitive swimming is that I am able to swim and train with my friends.
Training is more enjoyable when swimmers cooperate and swim with each other.
I am always glad to join my fellow swimmers for social gatherings such as parties, dances, etc.

IV. Training:
Champions: –
I prefer to have my swimming training planned well in advance so that I know what will occur.
I want my times to improve continually in training.
Champions and other Finalists: –
I like training programs which include a lot of variety (i.e. the swimmers are always doing something different).
When my race times improve, I am motivated to train more and harder.

V. Pre-Competition:
Champions: –
If I am troubled before a race, I know what to do to get myself "up" so that I perform my very best.

When I am listening to the starter's commands in a race, I always concentrate on moving fast and diving far.
At the start I always concentrate on listening for the gun.
I always use the information and experience gained in a race to modify my plan for my next race.
Champions and other Finalists: –
I like to set my own goals for the times to be swum in each meet.

VI. Competition:
Champions: –
I think I perform better and put more into competition than I do into training.
If I fall behind in a race, I always make the race a test for myself to do my best time and effort.
If the odds are really against my winning a race, I am still always able to produce my very best effort.
The more important the race, the more enjoyable it is.
Champions and other Finalists: –
If I am not familiar with a pool that is to be used for competition, it will not affect my times by making them worse.

VII. Motivational Features: –
Champions: –
I like swimming because every training and competitive swim is a challenge.
I want to be able to place frequently in races.
I know what I want to get out of swimming.
Champions and other Finalists: –
I want to get as much information on all aspects of swimming, for example how to train, the correct techniques, how to prepare for races, as I can.
I like to know my progress and improvement in event times, accumulated training distances, and techniques.
My goals in swimming include improving my times in all events, not just my specialty.
One of the great satisfactions from competitive swimming is getting to travel away to swim meets.
I would very much like to be the swimmer who stands on the victory stand after a race.

I want to become a national champion in at least one individual event.
I want to be selected for a national team.
I want to establish records in individual swimming events.

DISCUSSION

All finalists at national championships could be expected to share many psycho/social characteristics important in achieving this high performance level, and the present study lists as many as 21 such features. However, the 20 characteristics common only to the gold medallists is a remarkable number. This multiple cohesiveness of the champions lends support to the view that these features do play a positive role in the performance equation. That the non-winning finalists display vast variability, with only one specific characteristic in addition to the 21 shared with the champions, provides further strength to this contention.

In the theme clusters below, the characteristics specific to the champions or non-winning finalists, are evaluated for their effects on performance. Characteristics common to both are not considered since they are not of relevance in a comparative assessment.

I. General Features:
The champions' report of good psycho-somatic health in conjunction with coping strategies to effect controlled, positive emotive states [4, 5, 8] are clearly important foundations for athlete development, and particularly for achieving stability of performance. The elevation of swimming to pre-eminence in life can unleash maximal performance-building resources, although caution may be advised concerning an 'all-eggs-in-one-basket' syndrome whereby uni-dimensional objectives in life could generate vulnerabilities generated by a lack of countervailing balance-producing elements.

II. Relationship with Coach:
The gold medallists' cooperative relationship with their coach indicates a fruitful, symbiotic learning situation for both [9]. Since innovation in sport generally emanates from athletes, this feature of the swimming champions bodes well for the development of the sport. The single characteristic of the non-winning finalists meeting the

inclusion criterion is found here; -that learning is best when coach-directed. This may reflect an over-dependency on one source of knowledge, and a lack of confidence in personal analysis and reflection capacity. A more independent search for knowing could drive a steeper development curve.

III. Relationship with Swimmers:
The champions illustrate here a powerful focus on self not shared by the other finalists. To wish to train alone from time to time, and to discount the importance of overall team performance, is a territorial marking by the champion that is striking in that it occurs in a sport that despite its individualistic nature, is recognized for the intense proximity of its participants in training, and also in the competition context where team scores are often vividly proclaimed. Moreover, this is in the cultural context of Norway, with its strong collectivist tenor, and where being grouchy in social settings is unlikely to escape negative sanctions. That in spite of this, the champions navigate with a strong focus on self, affirms that concentration on the personal task at hand is of essence when facing the challenges of personal development. In addition, it should be noted that states such as grouchiness, a deeply felt emotion that at first glance might be surmised to have negative consequences, may on the contrary be performance productive [4].

IV. Training:
Since competition performance is a logical extrapolation of training performance, the many dimensions of training call for deeply reflective coaches and swimmers. Gold medallists report desiring long-term structure and predictability in their training, so that they know what will occur. This longitudinal pre-training knowledge may be viewed as wishing to ensure that sufficient time will be available for mental preparations and rehearsals of the physical, technical, and psychological states appropriate for the training sessions ahead [5, 8, 12]. This feature is consonant and complementary to the champion characteristic of wishing training times to fluidly improve as training progresses. This desire could only with difficulty be viewed as realistic without the precondition of predictability in training programs. With the, by swimming's nature, largely coach-directed training sessions, it is paramount that coaches be aware of these

champion desires so that training can be planned accordingly. Time improvements in training spur motivation, which then mobilizes [13] and develops resources, leading to further improvements. Of essence in this orchestration are the prior processes of mental preparation.

V. Pre-Competition:
In this critical phase [2, 5, 8] where much can disturb the optimal performance, the champions have clear, largely helpful, routines and skills. Their generalized coping capacity, noted earlier, is here concretized in the cauldron that is the competition pool. On the starting blocks, however, a contradiction emerges. A focus on moving fast and diving far reflects a productive, self-controlled, task-oriented approach. However, this is offset by the report that attention is simultaneously siphoned off in the direction of listening for the gun. Full attention cannot be in two locations at the same time. Here the champions, as well as swimmers at other levels, may be well advised to concentrate on their own optimal start motions. After each race, the champions systematically build on the experiences generated in their preparations for the next race. With this strategy, they ensure that race planning modification is steered by full, fresh, race data; -in particular this means that negative race experiences (not always pleasant to consider) are also given their due in the learning and development process. In this manner the fuel of motivation is maintained, regardless of performance curve swings.

VI.Competition:
In this, the celebration of the swimming life, the champions, again, show deep and positive homogeneity in their approach. They report stretching themselves beyond their training boundaries, and epitomize their coping capacities to ensure high quality performance regardless of difficulties encountered [5, 8]. Moreover, their stated enjoyment of the racing experience is directly correlated with event importance, paving the way for peak performance [3, 6] when it really counts. The joy of emotion facilitates the generation [13] of the very physical, technical, and mental processes that make such peaking possible.

VII. Motivational Features:
Motivation stokes the fires of performance, and in sport psychology this has long been recognized [7]. The many [8] characteristics shared here by all finalists is vivid documentation of this. Without the hunger

of motivation it is unlikely that national finals can be reached notwithstanding talent in all other areas of performance execution. In addition to the 8 common features, the champions illustrate 3 further, specific, characteristics. The pleasure experienced in their drive to meet the challenge of each and every training and competition swim demonstrates a detailed and highly mobilized focus that meets the demands for a systematic longitudinal shaping of performance capacity. The specificity principle could not be more vehemently lived [9]. This important disposition of the champions is closely related to their wish to frequently place in competition; -indeed it is a predisposition. Finally, the certainty of the champions concerning their overarching objectives for their swimming careers provides a confidence and dignity to their pursuit that is a deep resource for mastering the vicissitudes of the journey.

Closure: Notwithstanding the many shared characteristics in the psycho/social dimension between swimming champions and non-winning finalists, their distinctions as evidenced in this investigation are exceptionally clear. The cohesiveness of the gold medallists in this sphere is etched in the nuanced commonality of their approach to swimming. The many characteristics in question are almost without exception anchored in well established practices of performance enhancement. In contrast to physiological and biomechanical factors, many psycho/social elements of performance are open to relatively rapid, low energy-cost development. That the non-winning finalists, had they absorbed the victors' repertoire of these characteristics, would have increased their possibilities of joining the champions' circle is a scenario that swimmers and coaches might well reflect upon. With the growing homogeneity of swimmers; anthropometrically, physiologically, and biomechanically as competition in swimming intensifies, it stands to reason that attention to performance advantage be directed to the more heterogenous area of psycho/social elements. The stark distinction between champions and those not quite reaching that status shown in the present study clearly points in this direction. It may well be that the non-winning finalists were not substantially different from the champions in the non-psycho/social elements of the performance equation. But since psycho/social skills are decisive in determining the degree to which athletes' other capacities can, in fact, express themselves in the competition situation, then the assertive development of the psycho/social area is essential if athletes are to do themselves justice.

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Correspondence to:
Nils Vikander
North-Troendelag University College
Department of Physical Education
Roestad,7600 Levanger
Norway

PSYCHO/SOCIAL CHARACTERISTICS OF SWIMMING CHAMPIONS: WHAT ARE THE IMPLICATIONS OF GENDER DISTINCTIONS?

N. O. Vikander[1], R. K. Stallman[2]
[1]Nord-Trøndelag University College, Levanger, Norway
[2]Norwegian School of Sports Sciences, Oslo, Norway

ABSTRACT

Gender distinctions in the preparation of athletes has received increasing attention commensurate with the recognition of gender issues generally in post-modern society. The present study investigates this dimension in the psycho/social arena at the high performance level in swimming. Items of the Vikander & Stallman Swimming Champions Characteristics Checklist (SCCC) responded to in a like manner by 75% or more of Norwegian National Senior Individual Champions, 9 women and 9 men, were examined for gender-specificity and clustering tendencies. Sixty-one (61) of the 242 PICS items met the 75% inclusion criterion, of which thirty-two (32) were gender-specific. These 32 characteristics were distributed in 7 theme areas as follows: General Features (6), Relationship with Coach (2), Relationship with Swimmers (3), Training (7), Pre-Competition (3), Competition (4), and Motivational Features (7). Items were listed as: Specific to Women (8) and Specific to Men (24). Implications of gender differences for swimmer development and performance enhancement are discussed, as are those for coaching practice. Primary function of the inquiry is to elevate the appreciation and implementation of the psycho/social sphere in the aquatic performance equation, as based on the modelling features of champions, with particular attention to gender differentiations. As a tool for practitioners and researchers, the procedure outlined here lends itself well to longitudinal application.

Key words: psycho/social features, champion swimmers, gender issues, coaching

INTRODUCTION

Issues of gender have become increasingly volatile in post-modern society. The world of sport has not been immune to these developments, indeed it has often been in the public eye in view of the history of sport as a largely male domain. As women have moved into sport, so has sport needed to address gender issues in the preparation for performance [17]. Swimmers at all levels normally train in gender-mixed conditions, and often under a single coach. Although each swimmer needs individual attention according to personality and physical as well as technique parameters, there are also gender concerns. Where features distinguishing genders are revealed, appropriate care needs to be taken by the practitioner. The coach needs to be cognizant of nuances in this area, and should be especially alert to signals from the gender different from self. The present study examines gender differences of champion swimmers in their psycho/ social characteristics with the purpose of sensitizing swimmers and coaches to the importance of incorporating these dimensions in performance preparation, and in particular, to raise the awareness of possibilities for constructive cross-gender learning. In comparison with the well-researched areas of anthropometry, physiology, and biomechanics [2], the psycho-social dimension of swimming has received modest attention, notwithstanding its greater potential for lower time/energy cost performance-enhancing interventions.

MATERIALS AND METHODS

The Swimming Champion Characteristics Checklist (SCCC) [16] based on the Rushall [13].

Psychological Inventories for Competitive Swimmers (PICS) was administered to 18 Norwegian Individual Senior Champions (9 women, 9 men). Items in each of the sub-samples of 9 swimmers meeting the Rushall [11] criterion of a minimum 75% response commonality were extracted as indicative of deeply anchored characteristics. Consequently, in this study, a minimum of 7 of 9 women and 7 of 9 men swimmers (77.8%) needed to answer similarly for the feature to merit inclusion. Items of gender-specific nature were examined for clustering tendencies and were evaluated for performance enhancing potentialities for own as well as opposite gender, and also for their implications in coaching practice. Although some items relate to more than one cluster, decision on placement was made according to judgment of primary focus. Gender-common items were not assessed since they were not of relevance in a comparative study.

RESULTS AND DISCUSSION

Thirty-two (32) of the 242 item PICS met the criteria for inclusion, and were found in the 2 gender-categories as follows:

1. 8 Items Specific to Women
2. 24 Items Specific to Men

The 32 items were distributed in 7 theme clusters in the following manner:

I. General Features: Women: 3, Men: 3
II. Relationship with Coach: Women: 1, Men: 1
III. Relationship with Swimmers: Men: 3
IV. Training: Women: 2, Men: 5
V. Pre-Competition: Women: 1, Men: 2
VI. Competition: Men: 4
VII. Motivational Features: Women. 1, Men: 6

I. General Features:
Specific for Women:

a) I keep my swimming things well-organized and ready for immediate use.
b) I make a point of not being absentminded or forgetful of details about swimming.
c) I have always been free from vague feelings of ill-health, such as obscure pains, digestive upsets, awareness of heart action, etc. during training and competition.

Specific for Men:

a) I consider that swimming is the most important activity that I do.
b) Decisions concerning my swimming are governed more by carefully thought out reasons.
c) I would like my parents to be interested in and approve of my efforts in swimming.

Since this theme is an omnibus category, it is not surprising that the features listed are of varying nature. The women present themselves as organized, disciplined, efficient, and focused. They are detailed and concrete, and by this show that swimming is high priority in a "from-the-ground-up" fashion. The men's approach is more "from-the-top-down" – swimming is simply "...the most important activity...", and everything should follow from that. Their well thought-out decisions reflect this. Good health, the foundation for performance, is experienced by the women in a way that indicates they are sensitively aware of the role of the mind in health. That the men view parental support as valuable in their athletic efforts, a factor that has been documented elsewhere [9], shows an understanding of the importance of the emotive/motivational dimension of performance, a juxtaposition to the cognitive feature expressed in their decision-making. Reflections: All these characteristics can be viewed as positive for performance, although the men's placing of swimming into life pre-eminence may make them vulnerable to over-training/stress [8]. This may partially explain why they do not concur with the women's good health. Concerning cross-gender learning, all these features could be cultivated, though the women's health characteristic would likely pose a challenge for the men. Finally, in decision-making, it should be noted that a process based on values may be equally meritorious as one founded on reason [1].

II. Relationship with Coach:

Specific to Women:

a) I would like the coach to tell me that he/she likes the way that I am training or performing.

Specific to Men:

a) I learn things about swimming best when they are explained by a coach.

The coach is needed by the women for recognition and approval – verbal rewards which build positive emotions, thus fuelling motivation. The men are more cognitively oriented, desiring the coach as a source of information in the learning process, another possible route to motivation development. Reflections: Both preferences may be viewed as constructive and amenable to cross-gender learning. However, for coaching approval to be effective it must be deserved, and for both such approval and for information delivery, the swimmer should be cautious of becoming too dependent on the coach, thus diminishing personal responsibility for development.

III. Relationship with Swimmers:
Specific to Men:

a) I would like other swimmers to notice my swimming and to talk to me about it.
b) If I make an awkward social mistake among other swimmers I can soon forget it.
c) I have some characteristics in which I feel definitely superior to most swimmers.

There are no shared features among the women in this cluster, indicating great heterogeneity. Whether this relates to anecdotal evidence of female peer relational problems in competitive settings should be investigated. The men's array of features, on the other hand, indicates a measure of homogeneity. Their desire for peer contacts has both informational and motivational aspects; -both positive for development. The men's solid identity illustrated by successful coping with social errors points to a sound foundation for personal and athletic development. Lazarus and Folkman [4] maintain that interpersonal stress forms the majority of the human stress experience, and by reducing such stress the athlete has more performance-related capacity available since, as Rushall indicates [11], the individual has finite stress-coping resources. It is well to note in this regard that the swimming environment in both training and competition is highly congested, and the potential for interpersonal stress thus magnified. In the third male feature, hesitancy in expressing superiority over peers is not expressed, in spite of the positive relations mentioned. This assertiveness is unusual in Norwegian culture, but is of importance in establishing a confident and positive internal climate leading to performance enhancement [6, 10]. Reflections: The male features could well be emulated by the women in the interest of swimming development. An open and constructive approach to team-mates implies the opening of a vast source of informational and motivational feedback. The single coach can never match the frequency of contact with the individual athlete that swimmers can have with each other. Mobilizing the swimmers in this direction can be viewed as a key process of coach psycho/social engineering in the interest of a rising supportive-climate spiral.

IV. Training:
Specific to Women:
a) I seldom miss training through illness.
b) I am very willing to try new things in technique even though they feel very different and uncomfortable.

Specific to Men:
a) I prefer to have my swimming training planned well in advance so that I know what will occur.
b) I like to compete against at least one other swimmer in every repeat that I do at training.
c) No matter how much time is required for swimming training, I am prepared to do it.
d) One of the major reasons that I am training for swimming is so that I will qualify to go to the national championships.
e) I would be prepared to train for many years if it gave me a chance to become an Olympic champion.

Since competition performance is an extrapolation of the quality of training, this cluster is of unparalleled importance. The women confirm their good health by rarely missing training, meaning that good control is exercised over the development process. They also illustrate a further cornerstone of development, an openness to innovation and experimentation, notwithstanding the nearly always associated unpleasant stresses of attempting something new. The men swimmers display a much larger number of common training features than do the women. They are organization men, wishing long-term structure and predictability in their training. This can lead to a positive feeling of control and progress, lending meaning to the daily details of swimming. Moreover, it can facilitate a systematic growth of psychological skills in that mental preparation for workouts can be executed in an organized way. On the other hand, however, commitment to plans lowers the possibility for constructive flexibility as well as opening another door to over-stress vulnerability when expected adaptations to training fail to materialize. The men's desire to simulate competition in training serves the specificity principle well. Since actual competition is only a miniscule proportion of a swimmer's life, this approach augurs well for performance development. The last three male characteristics all express the deep determination with which these champions regard their sport. They are open-ended concerning the time they are prepared to devote to training, and their ambition-levels of national championships and even Olympic victory are clear indicators of a willingness to execute the needed training volumes. Reflections: In the cultivation of all these features there are positive cross-gender learning opportunities. The men may need to apply a more holistic approach to their swimming/life-in-general in order to approach the health-foundation state of the women. In this regard, however, there is evidence [8] that to achieve ultimate performance levels it may be necessary for at least some to exceed health boundaries.

V. Pre-Competition:
Specific to Women:
a) I always mentally rehearse my race plan before an important race.
Specific to Men:
a) If I lose confidence before a race, I always know how to recover it.
b) I always use the information and experience gained in a race to modify my plan for my next race.

In the pre-competition phase there is little that can be done to elevate the upcoming performance potential, but much can be done to ensure that all trained capacities will be utilized [3, 10]. In the women swimmers the consistent mental rehearsal of race plans shapes a confident mind-set: "I can execute this; I have already done it successfully so many times." The men, on the other hand, prepare for upcoming races by modifying plans according to past race experience, a very concrete and information-oriented approach. These men champions do, however, express important psychological skills in their coping capacity to recover lost pre-race confidence. Reflections: All three features are clearly performance enhancing [6, 10], and should not be difficult to implement in a cross-gender learning situation.

VI. Competition:

Specific to Men:

a) I think that I perform better and put more into competition than I do into training.
b) The main reason I compete in races is to see whether or not I have improved.
c) If I fall behind in a race, I make the race a test for myself to do my best time and effort.
d) If the odds are really against my winning a race, I am still always able to produce my very best effort.

In this feast in the swimmer's life, the competition, it is striking to note that the women champions have such great variability that they have no features in common. On the other hand, their men counterparts share 4 characteristics. First, the men swimming champions claim that both performance quality and effort in competition surpasses that which they exhibit in training. Although this appears appropriate, it should be kept in mind that competition is a result of training, and if training quality and effort were elevated, then competition consequences should be commensurately enhanced. An earlier study [14] by Stallman, Vikander, & Freim found greater male motivation for competition, as well, among male compared with female swimmers. The remaining 3 male features are all in the sphere of a process-oriented, internal-comparative approach. This is highly productive for development in that it is open-ended, avoiding the self-limiting goal of being "best" which relates to external comparison, and replacing it with "becoming better" which has no imposed ceilings. Reflections: The women champions could well emulate the men in these characteristics, with the caution proviso above on training/competition quality/effort. Perhaps an equally high focus on quality and effort in training as well as competition should be a goal to strive for?

VII. Motivational Features:

Specific to Women:

a) I want to get as much information on all aspects of swimming, for example, how to train, the correct techniques, how to prepare for races, etc., as I can.

Specific to Men:

a) I like swimming because every training and competitive swim is a challenge.
b) I like to keep detailed records of all my swims so that I can monitor my own progress.
c) I would very much like to be the swimmer who stands on the victory stand after a race.
d) I would like to see my name placed on a record board where everyone could see it.
e) I know what I want to get out of swimming.
f) I like to set the ultimate goals for my swimming.

In this final cluster, there is, again, a remarkable difference in the number of features common to each gender. The single woman characteristic concerns the desire to gain as much information as possible about all dimensions of swimming. This hunger is concrete, detailed, and all-encompassing, and documents a thorough "bottom-up" approach to building a foundation for performance. Implicit in it is an eclectic-directed independence which connects to the earlier reflected willingness to experiment and innovate. Together, these merge into a disposition highly favourable for performance progress. In common for the men champions were as many as 6 motivational features. Enjoying every swim as a challenge deeply reinforces the earlier noted positive focus on the process of performance. Keeping detailed written records of training and competition is a well-documented source, not only of information for planning, but also for creating commitment and motivation. The desire to gain the podium and to have one's name visible as a record-holder is a statement of appreciation of recognition in the public arena in the external-comparative sense. As a supplement to their internal process-focus discussed earlier, this product-perspective of performance can be viewed as a spice in their motivation-dimension. After all, these are champions, and the podium and records are within their documented grasp. The final two characteristics are overarching, umbrella perspectives. Knowing what to gain through swimming, and setting ultimate goals in the sport, are closely intertwined. The latter is the high end point of the goal-setting process. Goal-setting is one of the most rigorously researched performance enhancement strategies available [5], and the self-formulation of ultimate goals generates a commitment and a dignity to the trials and variegations of the long journey. Reflections: There are no motivational characteristics among these that could not with advantage be included in the ambitious swimmer's repertoire. A caveat might placed on the written record keeping in that this expression of bureaucratization in sport would for some have a de-motivational effect. It is important to be cognizant of this in the coaching role. The motivational features listed above are all well suited to cross-gender learning.

Closure: Since swimming champions differ substantially from non-winners in psycho/social characteristics, possessing many such features in common [15], it should not be surprising that in the present study, as many as 29 such characteristics were gender-common. This commonality may be interpreted as important in their achievement of champion status. Nevertheless, the present investigation has revealed striking gender-differences of champions. While the women swimmers shared 8 psycho/social features, their male counterparts showed 24, a full three times as many. Whether this task is an anomaly, or is generalizable in the swimming world, is a task for future research. If a general pattern, this should stimulate further investigation into underlying factors. Regardless of the research to come, it would appear well to implement a two-pronged coaching approach based on the insights generated by the study at hand. Coaching sensitivity to gender differences of a psycho/social nature should be paramount in the mixed-gender, spatially compressed arena that is swimming. Of special importance here is a call for greater understanding of women swimmers by the male coach. With the male preponderance among swimming coaches, this is the direction of insight most needed. The second prong refers to the stimulation of cross-gender learning, and here the main direction appears to be for facilitating the absorption of male modelled features by women swimmers. Psycho/social differences between the genders should in any and all cases be understood as served opportunities for learning from one another. The characteristics exhibited by the swimming champions are, virtually without exception, to be viewed as important for performance. The coach must, of course, be ready to in a nuanced manner adjust the pedagogical process so as to fit the unique profile of the individual. Of essence is this individualization in the pre-competition and competition phases where high level athletes through their careers develop often idiosyncratic patterns. Overall, it is of interest to note that if it is possible to argue that there is a tone, or timbre, to the characteristics distinguishing the genders, then in the present study it may be suggested that they point in the direction of what in the post-modern world is frequently termed gender-stereotypical distinctions. For the women, their features appear "softer", while the men's seem "harder". This is in stark contrast to the Vikander, Solbakken, and Vikander [17] study of international medallist cross country skiers who displayed strikingly "gender-inversion" stereotypical features.

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Correspondence to:

Nils Vikander
North-Troendelag University College
Department of Physical Education
Roestad, 7600 Levanger
Norway

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COULD SWIMMERS LEARN FROM CROSS COUNTRY SKIERS? – AN ELITE CROSS-SPORT ANALYSIS OF PSYCHO/SOCIAL FEATURES

N. O. Vikander[1], R. K. Stallman[2], T. Solbakken[3]
[1]Nord-Trøndelag University College, Levanger, Norway
[2]Norwegian School of Sport Sciences, Oslo, Norway
[3]Hedmark University College, Elverum, Norway

ABSTRACT

The Norwegian model of elite athlete development has in recent years included cross-sport contact to stimulate exogenous learning in the interest of performance enhancement. The objective of the study was to investigate whether this approach has theoretical merit in the case of the potential benefits of international level swimmers absorbing sport-specific psycho/social characteristics of world elite cross country skiers. Although apparently dissimilar, the two sports share commonality in their cyclical, rhythmical, symmetrical, whole body functional, gender egalitarian, and closed-skill properties expressed in mainly 'contact-less' conditions in individual and relay events. Eighteen [18] swimmers and twenty-eight [28] skiers responded to similar instruments resulting in thirteen [13] skier-specific characteristics in the following clusters: General Features [2], Relationship with Coach [1], Relationship with Athletes [1], Training [5], Pre-Competition [3], and Motivational Features [1]. The skier-specific features were analyzed in terms of their appropriateness for swimming performance enhancement. Implications for coaching are also considered, as is the further research needed for the empirical documentation of the benefit potential of the cross-over scenario.

Key words: performance enhancement, cooperation, exogenous learning

INTRODUCTION

Norwegian strategies of elite athlete development in recent years have included the facilitation of contact between athletes and coaches within and outside the training context. The rationale for these initiatives is the view that such contacts would challenge established preparation routines and beliefs. In this manner cross-fertilization is expected occur in the form of experimentation and learning, resulting in performance enhancement. In the present inquiry, the conjectures upon which this initiative is based are investigated within the psycho/social arena of sport, the area of greatest variability in the athletic community, and also the dimension of performance most amenable to absorption and implementation from sports outside the personal sphere. The focus in the study is on high level swimmers, and whether psycho/social characteristics of elite cross country skiers, not shared by the swimmers, might be of benefit also to them. The two sports appear very disparate; cross country skiing is a generally longer duration, outdoor winter sport, conducted over geographically extensive and varied natural settings, and offering low transparency for spectators and coaches. Swimming, on the other hand, is a mainly indoor, shorter duration activity, within a largely standardized, purpose-built environment with a centralizing, small-area character facilitating close monitoring coaching and spectating; seemingly a world away from skiing. Notwithstanding these distinctions, however, the two sports do share substantial commonality: cyclical, symmetrical, and rhythmical whole-body movement patterns, expressed through a variety of techniques under largely closed-skill, 'contactless' conditions in individual and relay events, and within a gender-egalitarian context. This tension between similarity and difference created an especially intriguing opportunity for investigating the potentialities of this Norwegian approach to athlete development. Particularly challenging, as well, was to examine whether this approach could be fruitful even at very high performance levels.

MATERIALS AND METHODS

The comparison of swimmers and skiers was made possible by two similar sport-specific instruments, the Swimming Champion Characteristics Checklist (SCCC) [15] and the Cross Country Ski Champion Characteristics Checklist (CCSCCC) [14]. Both are based on sport- and environment-specific instruments developed by Brent S. Rushall and co-workers as a reaction against trait-oriented efforts to delineate psychological and behavioural profiles. The two such instruments connected to the present study were the Psychological Inventories for Competitive Swimmers [11] and the Behaviour Inventories for Cross Country Skiers [8]. The inquiry analyzed the responses of 18 Norwegian senior national swimming champions and international representatives to the SCCC, in relation to those of 28 Olympic and World cross country ski medallists to the CCSCCC. The Rushall [10] criterion of a minimum of 75% respondent agreement, indicating a securely anchored characteristic, was necessary for it to warrant inclusion (21 skiers = 75.0%, and 14 swimmers = 77.8%). Items of a strictly sport-specific nature were eliminated in the comparative analysis, such as, "When I am listening to the starter's command in a race, I always concentrate on moving fast and diving far" and "I feel confident I can select the correct skis for a race". More general items not part of both instruments upon which the checklists were based, were also excluded. The items remaining were reformulated in a sport-neutral manner for presentation purposes, categorized as specific to champions of each sport (or common to both), and finally distributed among 7 theme clusters. The clusters were shaped by the necessity of being relevant for both checklists. Though the nature of some items could place them in more than one cluster, their final classification reflected an assessment concerning predominant focus. Skier-specific features surviving the selection process were examined for performance-enhancing applicability for the swimmers. Implications for the swimming coach role were also assessed, as were the possibilities of sport-comparative research of this modality in general.

RESULTS

Forty-one [41] items met the criteria for inclusion and were distributed in the three categories as follows:

1. 13 Skier-Specific Items
2. 13 Items Common to both Sports
3. 15 Swimmer-Specific Items

Characteristics of skiing champions that differentiate them from champion swimmers:

I. General Features: 1) I like to set the ultimate goals for my athletic career, myself. 2) I would like my parents to be interested in my efforts in my sport.

II. Relationship with Coach: 3) I prefer my coach to tell me privately when I have done something wrong.

III. Relationship with Athletes: 4) I can accept criticism from fellow athletes.

IV. Training: 5) I consider myself to be very enthusiastic about training. 6) No matter how much time is required for training, I am prepared to do it. 7) I try to do everything as well as I can in training. 8) I like to have a goal set for most things I do in my training. 9) I try my best in training.

V. Pre-Competition: 10) I stay in control of my pre-race preparations. 11) I prefer to warm up for an important race by myself. 12) I would not like to be able to 'psych-out' other competitors before a race.

VI. Competition: No ski-specific features.

VII. Motivational Features: 13) Just being able to feel the motion involved in my sport makes training enjoyable for me.

DISCUSSION

Of the forty-one characteristics in total that met the selection criteria, thirteen or 31.7% were common to both sports. That nearly one in three features was established in both indicates that the athlete profile/sport requirement match has a substantial degree of similarity. This supports the view that swimming and cross country skiing share sufficient elements to justify bringing them together for analysis. On the other hand, the same number [13] were found to be skier-specific, while as many as fifteen [15], or 36.6% of the 41 in total were established characteristics only for the swimming champions. The numerous sport-specific features fuels the possibility that both sports could benefit from the example set by the other. The paramount task, then, is for the practitioner in the present swimming-applied context to assess the appropriateness of 'importing' features from elite skiers for cultivation among champion swimmers with the intention of elevating performance still further. Clearly, sensitive coaching should always prescribe an individualized approach in this regard, although features may be found that are of such nature as to indicate broad, general applicability. The skier-specific features will now be examined in their clusters with these swimmer-perspectives in mind.

I. General Features: 1) Goal-setting is a solidly established enhancer of performance [2], and should be implemented at all time-levels by the ambitious athlete, including at the ultimate career level. Swimming, yet more so than skiing, is a globalized sport with all that entails in rising competition intensity, so goal-setting of this type should be all the more important for swimmers who wish to make their mark. Setting goals oneself provides further likelihood of performance elevation by reinforcing goal achievement through the commitment process whereby a form of personal 'ownership' of the goal is formed. Reflection: Swimmers would benefit by emulating the skiers. 2) The importance of the sociological primary group, and especially that of the parents, for elite skiers, has been documented [7]; it would be reasonable to expect it would be similar for swimmers. Reflection: The swimmers would benefit by cultivating their parents' interest in their sport.

II. Relationship with Coach: 3) General civilized discourse calls for delivering criticism in private. That the swimmers do not indicate a wish that their coach comply with this may, on the one hand, mean that this is not an issue; -their sensitive coach would never voice criticism publicly in any case. On the other hand, it may mean that swimming creates a trusting social environment where public criticism is more readily accepted. Or, does the constricted space of the swimming pool mean that it is difficult to find privacy for any communication? The nuances of this issue require more detailed investigation before clear recommendations can be expressed. Reflection: Pending more knowledge, it would seem better to err on the side of courtesy, and advocate criticism in private; few swimmers are likely to prefer public criticism.

III. Relationship with Athletes: 4) The openness of the skiers to criticism from fellow athletes can be seen as a valuable disposition in the drive for development. Fellow athletes are highly significant others whose observations and resulting communications can be deeply meaningful. That this is a feature of the skiers and not of the swimmers, may be a reflection of swimming as a sport for generally younger people whose identity formation is less solidly established. Reflection: To accept and provide reflected criticism among swimmers, though likely stressful at first, would longitudinally be beneficial both for performance enhancement and personal development.

IV. Training: Since competition performance is a logical consequence of preparation, this cluster is of deep significance, mirrored by the many features exhibited here. 5) The positive emotion reported by the skiers is a performance enhancer well anchored in the psychology of sport [3]. Since the overwhelming proportion of time spent in one's sport is in training, it is clear that without enthusiasm in this setting, progress would diminish. Without a positive internal climate, neither physiological nor psychological capacities can be expressed to their potentials. Reflection: The swimmers would benefit from fuelling their training enthusiasm, probably no easy task since the limited variability of training possible in a swimming environment may place ceilings on enthusiasm cultivation. This is a serious challenge for coaches. 6) Both sports are known for their heavy training demands. The skiers, however, differ in their indicated willingness to be open-ended about this. With the growing intensity of competition in swimming, it would seem appropriate for ambitious swimmers to take the skiers' approach in this regard. Doing oneself justice in the sport appears to dictate this. 7) The concentration on quality training of the skiers, or as gold medallist, Thomas Alsgaard phrased it, everything important done in the right way (5), is surely a key component in their success. In as complex a technique sport as swimming, this should be a similarly effective recipe. Reflection: The swimmers would be well advised to follow the skiers' example. 8) The concrete, detailed goal-setting of the skiers in training is at the opposite end of the time-spectrum from the career goals discussed earlier. They are, however, probably even more important in that they inform the regular daily training process with sharpened objectives. There is a development vision for the training elements. Reflection: The immersion and commitment [4] implied in this approach would elevate swimmer development. 9) Trying one's best in training means a focus on the quality of effort by the skiers. To indicate this, signifies that the mobilization for the task at hand is maximal. Reflection: The swimmers would be well served to emulate the skiers in this regard.

V. Pre-Competition: Little can be done in the immediate pre-competition phase to elevate performance; -much, however, can be done to ensure that an optimal performance is, in fact, within reach [1] 10) Only by being in control during this period, like the skiers, is it possible to know clearly at the start of the event what the foundation is for the impending performance [9], and therefore, what validity the competition strategy has. If the skiers can master this coping in the face of their challenges in ski selection and waxing, then it should be possible for the swimmers. A difficulty facing the swimmers is the limited space for swimming warm-up, although finding more private space for other elements of the physical preparations, not to speak of mental rehearsals, should be possible through mapping pool building facilities. Outdoor meets provide greater opportunities for this as do indoor meets in the warm season when leaving the pool building extends the preparation control possibilities. An additional strategy would be to wear a headset, which in addition to dampening auditory distraction, sends a privacy message to others. 11) The skiers' preference of solitary warm-up is clearly a condition for being able to stay in control. Here the swim meet context can not fully replicate skiing where the skiers can simply leave the start/finish area and find their own sites in the woods for the ski warm-up. Reflection: Minimizing social interaction prior to race start is an important component in ensuring a predictable and optimal pre-race state. Swimmers would benefit from this skier feature. 12) Not only do the skiers demonstrate good sportsmanship in declining opportunities to 'psych-out' competitors, they also benefit from an enhanced focus on their task at hand, the race, by avoiding the dilution of such attention [12] inherent in the attempt to manipulate others. Reflection: The swimmers would be well advised to resist the psyching-out temptations integral to the tight social environment of their competition arena, from both fair play and personal performance perspectives.

The compact and sensorily highly intense swimming competition arena, then, calls for astute coaching action to facilitate the athlete preparation conditions recommended above.

VI. Competition: Although the swimmers had three features specific to them and there was one characteristic common to both skiers and swimmers, the skiers showed no features restricted only to them. This appears to reflect highly individualized approaches to the challenges of exceedingly complex cross country ski performances.

VII. Motivational Features: Motivation, the fuel of action, has a deservedly central position in the psychology of sport [6]. 13) The inherent joy of gliding over the snow is expressed by the skiers as sufficient reason for engaging in their demanding training. That this is the view of the very elite is illuminating in its focus away from the medals and associated commercialism of modern sport. This is an encouraging finding for the recruitment to sport in an increasingly problematic world. Reflection: It should be near at hand for swimmers to adopt this perspective since moving through the water is inescapably an experience in sensuous whole-body massage.

This inquiry has generated insight into many detailed dimensions of sport that would be difficult to achieve without a comparative analysis. The polarity inherent in the comparative approach challenges established practice and in the present case, this relatively simple and accessible strategy has resulted in useful information and inspiration for competitive swimmers. The present test of this Norwegian model indicates that the suppositions upon which it is based appear to have empirical strength under the proviso that the swimmers and their coaches are, in fact, open to the learning potential offered by the skiers. Further studies are needed to investigate the cross-over effects, potentially beneficial, of other sports selected for their theoretical mutual gain [13]. In addition, assessments need to be made of the conditions under which exogenous learning is effected, and what its consequence is for the performance equation.

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Correspondence to:

Nils Vikander
North-Troendelag University College
Department of Physical Education
Roestad, 7600 Levanger
Norway

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