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Research article

Muscle fibre type composition and body composition in hammer throwers

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Abstract

Aim of the present study was to describe the muscle fibre type composition and body composition of well-trained hammer throwers. Six experienced hammer throwers underwent the following measurements: one repetition maximum in squat, snatch, and clean, standing broad jump, backward overhead shot throw and the hammer throw. Dual x-ray absorptiometry was used for body composition analysis. Fibre type composition and cross sectional area was determined in muscle biopsy samples of the right vastus lateralis. Eight physical education students served as a control group. One repetition maximum in squat, snatch and clean for the hammer throwers was 245 ± 21, 132 ± 13 and 165 ± 12kg, respectively. Lean body mass was higher in hammer throwers (85.9 ± 3.9kg vs. 62.7 ± 5.1kg ($p < 0.01$). The percentage area of type II muscle fibres was 66.1 ± 4% in hammer throwers and 51 ± 8% in the control group ($p < 0.05$). Hammer throwers had significantly larger type IIA fibres (7703 ± 1171 vs. 5676 ± 1270μm^2, $p < 0.01$). Hammer throwing performance correlated significantly with lean body mass ($r = 0.81$, $p < 0.05$). These data indicate that hammer throwers have larger lean body mass and larger muscular areas occupied by type II fibres, compared with relatively untrained subjects. Moreover, it seems that the enlarged muscle mass of the hammer throwers contributes significantly to the hammer throwing performance.

Key words: Track and field, athletic throws, lean body mass.

Introduction

Hammer throwing is a track and field event with high power demands (Zatsiorsky, 2005). Human muscle power is thought to be determined mainly by the fibre type composition of the protagonist muscles, the magnitude of the muscular mass, which defines muscular strength and the neuromuscular activation level during movement (Moritani 2005). However, there are no reports regarding the fibre type composition of the protagonist muscles of hammer throwers while there is only one report regarding the lean body mass of moderate-level hammer throwers (e.g. hammer throwing performance of 55.09 m, Morrow et al., 1982). Previous studies, concerning a related track and field event, the linear shot put throw, have revealed that lean body mass (De Rose and Biazus, 1978) as well as the neuromuscular activation level during the competitive throw (Terzis et al., 2007) are important for throwing performance in well-trained shot putters. In contrast, the fibre type composition of the gastrocnemius muscle could not predict shot put performance in elite shot putters (Costill et al., 1976; Coyle et al., 1978). Moreover, a recent case-study reported that a world-class shot putter possessed a relative low percentage of type II muscle fibres (40 %) in his vastus lateralis (Billeter et al., 2003). Taken together, these data suggest that the fibre type composition is less important in determining performance in a powerful event such as the shot put. However, there are no data regarding the fibre type composition in vastus lateralis muscle of high-class hammer throwers, thus, the importance of this biological parameter for such human performance remains uncertain.

Various strength and power tests are used during the preparation period for hammer throwing. A previous report revealed that moderate hammer throwing performance was not related with vertical jump, long jump, sprint running, isokinetic strength, or various one repetition maximum (1RM) strength tests, in moderately-trained hammer throwers (Morrow et al., 1982). Nevertheless, the performance in such strength tests and field tests has not been yet described for well-trained hammer throwers. Thus, the purpose of the present study was to describe the muscle fibre type composition, body composition and strength/power performance in well-trained hammer throwers.

Methods

Subjects

Six well-trained, male hammer throwers participated in the study (age: 25.8 ± 5 years; height: 1.85 ± 0.04 m; body mass: 116 ± 6 kg; BMI: 34.1 ± 1.6 $kg \cdot m^{-2}$). All of the athletes were right-handed and had participated in organized hammer throwing training and competitions for at least 5 years. One of them ranked 8th in the 2003 world track and field championship, and 3rd in the European Championship of 2002. The mean hammer throwing performance of the subjects (72.17 ± 6.40 m) was at 84% of the current world record and at 88% of the best performance achieved at the 2008 Olympic Games. Before study entry and after being informed about the experimental procedures and the possible hazards of the muscle biopsy technique, all athletes gave their written consent. Eight male physical education students (age: 22 ± 1 years; height: 1.82 ± 0.04 m; body mass: 78.5 ± 8.0 kg; BMI: 23.2 ± 3 $kg \cdot m^{-2}$) served as a control group. They also gave their written consent after being thoroughly informed about the experimental procedures. Data for these subjects have been published before (Terzis et al., 2008b). The

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control group did not perform the hammer throw, neither the 1RM in clean and snatch because of lack of proper exercise technique. All procedures were approved by the Ethics Committee of the local institution.

Hammer throw

Hammer throwing performance was measured in late afternoon, at an ambient temperature of 19^0C. All athletes were in good condition and suffered from no injuries. However, since they were at the end of the pre-season preparation period, they had not participated in any hammer-throwing event during that specific year. Each athlete performed his individual warm-up (approximately 30 min) and subsequently performed six throws with a 7.26 kg implement. The best performance was recorded and further used in statistical analysis. Intraclass Correlation Coefficient (ICC) for hammer throwing performance was examined in two consecutive days (R = 0.93).

One Repetition Maximum squat, clean, and snatch

Assessment of maximal strength (1RM) in squat, clean and snatch was performed on another day according to previously described methods (Baechle et al., 2000; Terzis et al., 2008a). Briefly, after a short warm-up on a static bicycle and a few stretching exercises, subjects performed incremental submaximal efforts, until they were unable to lift a heavier weight. A three-minute rest was allowed between the trials. Maximal strength was determined for all of the three exercises in the same day in the order described above, with a rest period of 30 min between exercises. The ICC for 1RM squat, clean, and snatch 1RM was determined, in two consecutive days (R = 0.92, R = 0.93, R = 0.90, respectively).

Backward overhead shot throw and standing broad jump

Backward overhead shot throw performance (Dunn and McGill, 1991; Silvester, 2003) was measured on a different day, outdoors, on a standard circle, during the morning hours, using a 7.26 kg implement. Ambient temperature was 18 - 20^0C. Four trials were allowed for each athlete and only the best performance was used in statistical analysis. Fifteen minutes later, the athletes performed the standing long jump, indoors, as described previously (Adam et al., 1988). Three trials were allowed for each athlete and the best performance was used in statistical analysis. The ICC for backward overhead shot throw and standing broad jump was determined in two consecutive days (R = 0.92, R = 0.93, respectively).

Muscle biopsies and histochemistry

Muscle samples (Bergström, 1962), were obtained with suction from the middle portion of vastus lateralis of the right leg, 20 cm from mid patella. Samples were aligned, placed in embedding compound and frozen in isopentane, which was pre-cooled to its freezing point. All samples were kept in liquid nitrogen until the day of analysis. Serial cross-sections, 10 μm thick, were cut at -20°C and stained for myofibrillar ATPase after pre-incubation at pH 4.3, 4.6 and 10.3 (Brook and Kaiser 1970a; 1970b). Samples from all athletes were incubated at the same time in the same jar for each specific pH. A mean of 679 ± 68 muscle fibres were classified as type I, IIA, or IIX, from each sample (Staron 1997). The cross sectional area (CSA) of all the classified fibres from each sample was measured with an image analysis system (ImagePro, Media Cybernetics Inc, Silver Spring, MD, USA) at a known and calibrated magnification. Furthermore, the lesser diameter (e.g. "the maximum diameter across the lesser aspect of the muscle fibre", Dubowitz and Sewry, 2006) was measured for all the classified fibres. The ICCs for the percentage of type I, IIA and IIX fibres in our laboratory is R = 0.96, R = 0.95, R = 0.93, respectively. This was calculated in 14 muscle biopsies by analyzing the percentage distribution of different fibre types in two distinct micro-images of the same biopsy, each containing at least 200 fibres.

Dual X-ray absorptiometry (DXA)

A total body scan was performed (DXA model DPX-L, LUNAR Radiation, Madison, WI, USA) and analyzed using the LUNAR Radiation body composition program. Fat mass, lean body mass (LBM) and bone mineral density (BMD) were determined for the total body, the arms, the legs and the trunk. Two different investigators performed all analyses and the mean value was used in statistical analysis. The ICC for the DXA measurement in our laboratory in shot putters is R = 0.92.

Statistical analysis

Means ± SD were used to describe variables. Independed T-test was used to evaluate differences between the hammer throwers and the control group. Coefficient of variation was calculated (CV %: [SD / mean] · 100) as a measure of the homogeneity of each variable. Pearson's (r) product moment correlation coefficient was used to explore the relationships between different variables. One-way χ^2 analysis was performed between athletes and controls regarding their frequency distribution of type I and type II muscle fibre diameters. $P \leq 0.05$ was used as a two-tail level of significance.

Results

Hammer throwing performance was 72.17 ± 6.4 m. One RM in snatch was 131.7 ± 13 kg while 1RM in clean was 165 ± 12 kg. The rest of the performance variables as well as the variables regarding muscle morphology and body composition of the hammer throwers and the control group are presented in Table 1. The percentage of muscular area occupied by type II fibres was rather homogenous in hammer throwers (66.1 ± 4 %, CV = 6 %). A representative image of the muscle fibre morphology of a hammer thrower and a control individual is shown in Figure 1. Hammer throwers performed significantly better in all strength/power tests ($p < 0.01$, Table 1). The percentage of type I muscle fibres was lower in hammer throwers ($p < 0.01$), the percentage of type IIA muscle fibres was higher in hammer throwers compared to the untrained individuals ($p < 0.01$), while there was no significant difference in the percentage of type IIX fibres between the two groups (Table 1). Interestingly, the fibre cross sectional area was statistically different between the two groups only for the type IIA muscle fibres ($p < 0.01$,

Table 1. **Muscle morphology of the right vastus lateralis, body composition and selected performance variables, in well-trained hammer throwers and physical education students. Data are means (±SD).**

Variable	Hammer throwers	Controls
Type I muscle fibres (%)	39.9 (5.0) **	51.4 (7.0)
Type IIa muscle fibres (%)	51.1 (9.0) **	34.4 (6.0)
Type IIx muscle fibres (%)	9.0 (7.0)	14.3 (7.0)
CSA of Type I fibres (μm^2)	5793 (670)	4979 (1266)
CSA of Type IIa fibres (μm^2)	7703 (1171) **	5676 (1270)
CSA of Type IIx fibres (μm^2)	6554 (2040)	4893 (1260)
Type I fibre CSA (%)	33.9 (4.0) **	49.0 (8.0)
Type IIa fibre CSA (%)	57.3 (9.0) **	37.9 (8.0)
Type IIx fibre CSA (%)	8.8 (7.0)	13.1 (5.0)
Lean body mass total (kg)	85.9 (3.9) **	62.7 (5.1)
Lean body mass arms (kg)	10.5 (1.5) **	7.8 (.7)
Lean body mass legs (kg)	30.4 (1.9) **	21.9 (2.3)
Body weight (kg)	116.4 (6.2) **	78.7 (1.0)
Body fat (%)	22.4 (2.9) *	16.4 ± 5.9
Bone mineral density (g/cm^2)	1.484 (.046) **	1.264 (.08)
Backwards shot throw (m)	18.88 (1.80) **	9.45 (.4)
Standing broad jump (m)	3.09 (12.00) **	2.29 (21.00)
1RM Squat (kg)	245 (21) **	81 (12)

* and ** denote $p < 0.05$ an < 0.01 respectively. CSA: cross sectional area.

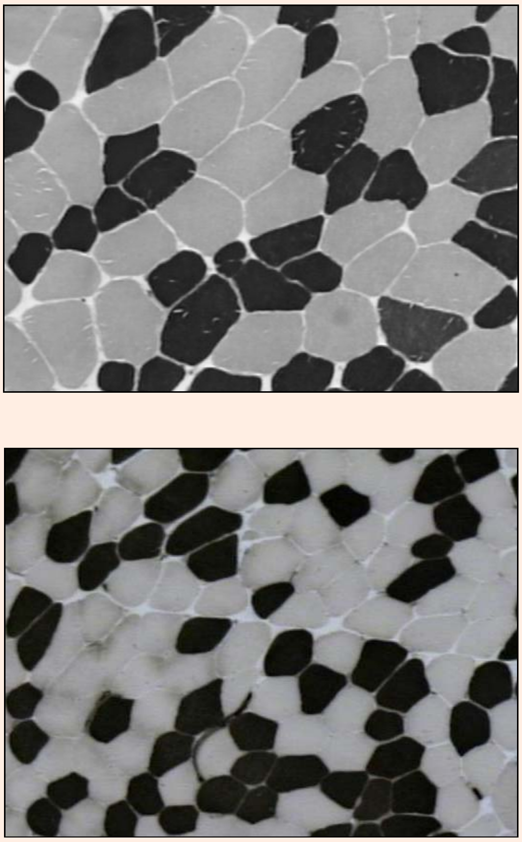

Figure 1. **Myosin ATPase (pH 4.3) from vastus lateralis of a hammer thrower (top) and an untrained young man (bottom). Dark-stained cells are type I muscle fibres. Bar = 100 µm.**

Table 1). Hammer throwers had greater lean body mass, bone mineral density and body fat compared to the untrained individuals ($p < 0.01$, Table 1). The frequency distribution for the diameters of type I and type II muscle fibres is presented in Figure 2. The mean fibre diameter for type II fibres was 74.1 ± 5 µm for the hammer throwers and 62.3 ± 5 µm for the control individuals ($p < 0.05$). The frequency distribution of muscle fibre diameters (Figure 2) revealed a significant higher percentage of type II fibres with diameters between 100 - 120 µm, for the hammer throwers ($p < 0.05$).

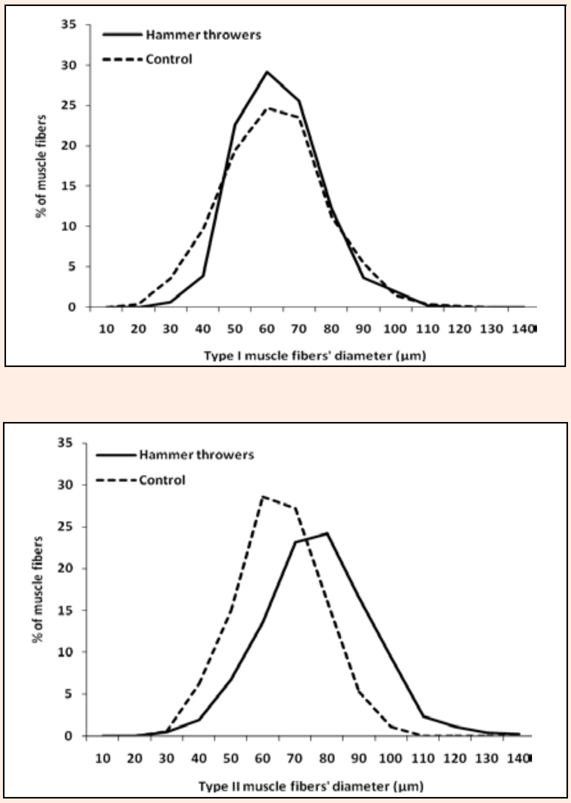

Figure 2. **Frequency distribution of type I (top) and type II (bottom) muscle fibre diameters from hammer throwers (solid line) and untrained young men (dashed line). Muscle biopsies were obtained from vastus lateralis.**

Hammer throwing performance was significantly correlated with backward overhead shot throw ($r = 0.95$, $p < 0.01$) as well as with total body ($r = 0.81$, $p < 0.05$), leg (r = 0.84, p < 0.05) and trunk (r = 0.85, p < 0.05) lean body mass. In contrast, low and nonsignificant correlations were found between hammer throwing performance and body fat (r = 0.14, ns), bone mineral density (r = 0.17, ns) and body weight (r = 0.35, ns). In addition, hammer throwing performance was significantly correlated with the CSA of type I muscle fibres (r = 0.93, p < 0.01) type IIA muscle fibres (r = 0.96, p < 0.01), and type IIX muscle fibres (r = 0.90, p < 0.01). In contrast, the correlation between hammer throwing performance and fibre type composition was low and nonsignificant (r = 0.41, ns).

Discussion

The aim of the present study was to describe muscle morphology of vastus lateralis, strength and power performance, and body composition of well-trained hammer throwers. Hammer throwing is a track and field event, which requires the production of high muscular power (Cook, 2006; Zatsiorsky, 2005). Human muscular power is mainly determined by the fibre type composition of the protagonist muscles, the muscular strength/mass and the level of the neuromuscular activation during the movement (Moritani, 2005). Type II muscle fibres can produce higher muscular power compared to type I muscle fibres (Bottinelli et al., 1996). Thus, it was hypothesized that well-trained hammer throwers would have a higher percentage of type II muscle fibres in their vastus lateralis muscle, larger muscle fibre cross sectional areas, and larger lean body mass compared with relatively untrained young individuals. The results of the study revealed that, indeed, hammer throwers have significantly higher lean body mass (+37%) compared with the untrained individuals. Furthermore, a higher percentage of type IIA muscle fibres was found in the group of hammer throwers and a comparable percentage of type IIX fibres between the two groups in vastus lateralis, although muscle fibre hypertrophy was limited to type IIA fibres. Most of the skeletal muscle hypertrophy can be attributed to the muscle fibre hypertrophy due to resistance training (Adams et al., 1993; Fry et al., 2004). In contrast, differences in the relative distribution of type IIA fibres in vastus lateralis might be the result of either training or genetic predisposition.

An interesting result of the present study was the homogenous muscle morphology in respect to the percentage area occupied by the type II fibres. Indeed, the percentage area of type II muscle fibres was 66 ± 4%, with a coefficient of variation (CV) of just 6%. This result might be related to the physiological demands of the training stimuli. It has been reported in the past that certain training stimuli lead to specific muscle fibre type and cross sectional area adaptations (e.g. Schantz et al., 1983). However, this notion requires further investigation. Since, this is the first work examining the fibre type composition in hammer throwers, these data cannot be compared with previous ones. However, there are some data available from shot put athletes, which might be helpful in the interpretation of the present results. In a pioneering study, Costill et al. (1976) found that the percentage of type II muscle fibre area in the gastrocnemius muscle of well-trained, male discus throwers and shot putters was (66 %) which is comparable to that found in the present study. However, in that previous study, the range of individual values was broader (50 - 97 %). In another study (Coyle et al., 1978), the percentage of type II muscle fibre area in gastrocnemius muscles of elite shot putters was also similar to the present study (62.1 %) but again the range of individual values was broader (range: 36.6 - 83.9 %, CV = 24 %). Furthermore, these authors (Coyle et al., 1978) reported that muscle fibre cross sectional areas were significantly higher in shot putters than in untrained subjects, although there was no difference in the fibre cross sectional area between type I and II fibres, in the group of shot putters. One very informative study regarding the importance of fibre type composition in throwing performance is the case report of the elite shot putter W. Günthör (Billeter et al. 2003). This study showed that this elite athlete possessed a moderate percentage (40 %) of type II muscle fibres in his vastus lateralis. However, he had a high type II fibre CSA (10,265 μm^2), thus, a high percentage area of type II fibres (66.6 %). This finding is in agreement with the results of the present study. Indeed, the percentage of type II muscle fibres of the best hammer thrower of the present study was 52.7 % (the lowest percentage of type II fibres in this group). However, his type II fibre CSA was the highest in this group (9110 μm^2). Thus, the percentage type II fibre area in his vastus lateralis was close to that of the rest of the group (60.9%). Taken together, these findings might suggest that the combination of the percentage and the hypertrophy of type II muscle fibres is important in the throwing events wherein a large external resistance is used (e.g. hammer and shot). Therefore, it seems that muscle hypertrophy plays an important role in these track and field events because it determines the absolute muscle cross sectional area occupied by type II muscle fibres, which most probably contribute significantly to such a fast and powerful performance. In contrast, Morrow et al. (1982) showed that lean body mass was not related with performance in moderate-level hammer throwers. The discrepancy between the results of the present work and those of that previous study might be attributed to the athletic ability of the subjects (hammer performance of 55.09 m in that previous study vs. 72.17 m in the present investigation) or to the method of LBM assessment (hydrostatic weighting and use of the Siri equation vs. DXA).

Another interesting finding of the present study was the relatively high percentage of type IIX fibres found in hammer throwers (9 ± 7 %) which was not significantly different from the control group. It is well described that resistance training in untrained or moderately trained individuals leads to a decrease in type IIX muscle fibres and a concomitant increase in the percentage of type IIA muscle fibres (Adams et al., 1993; Terzis et al., 2008b). Thus, it would be reasonable to expect that these strength-trained hammer throwers would have a relatively small percentage of type IIX fibres in their vastus lateralis at the end of the winter preparation period when the resistance training volume is maximized. Unfortunately, there are no previous data regarding the percentage of type IIX fibres in hammer throwers for comparison with the present results. However, a recent study reported an even higher percentage of type IIX MHC isoform distribution in vastus lateralis of well-trained bodybuilders (D'Antona et al., 2006) while an older study has shown an even higher percentage of type IIX muscle fibres in vastus lateralis of sprinters (Sjoström et al., 1988). As previously suggested (D'Antona et al., 2006), the relatively high percentage of type IIX muscle fibres in vastus lateralis of resistance-trained individuals might be due to intensive and longitudinal resistance training, a genetic predisposition or a hyperproteic diet. Another possible explanation for the high percentage of type IIX muscle fibres might be related to the phase of training of our athletes (i.e. the end of the pre-season preparation). Andersen and Aagaard (2000) have shown that the percentage of type IIX fibres can vary depending on the phase of resistance-training. Another possible explanation of the relatively high percentage of type IIX muscle fibres in hammer throwers might be related to a lack of consistent recruitment of this pool of fibres during training although, it is difficult to provide evidence for such premise (Enoka, 2008). Alternatively, this relatively high percentage of type IIX fibres might be due to the methods of analysis. ATPase histochemistry can identify muscle fibres as type IIX although these fibres might contain only small amounts of type IIX myosin heavy chains (MHCs) (Fry, 2004; Parcell et al., 2003; Pette and Staron 2001). Unfortunately, at this point we were not able to perform single fibre analysis for MHC isoform composition in order to determine the exact percentage of muscle fibres containing type IIX MHCs.

Total lean body mass correlated significantly with hammer throwing performance. Moreover, lean mass of the trunk and the legs were significantly associated with hammer throwing performance in this small group of experienced athletes. These findings were reinforced by the significant correlation found between the muscle fibre cross sectional area (of all fibre types) of vastus lateralis and hammer throwing performance. Taken together, these results emphasize the importance of muscle mass in hammer throwing performance. However, it should be emphasized that the number of subjects which participated in this study was limited (n = 6). Thus, all correlational data should be interpreted with caution until additional data are collected from a larger group of well-trained hammer throwers.

In comparison to a previous report on moderate-level hammer throwers (Morrow et al., 1982), the present athletes were of similar height, much heavier, with lower lean body mass and higher percentage of body fat, but performed better in strength/power/hammer tests. Bone mineral density of the present hammer throwers was higher than the control group and that reported for recreational weight lifters (Hamdy et al., 1994), but lower than that was found in highly trained power lifters (Dickerman et al., 2000). Bone mineral density in hammer throwers probably reflects bone tissue adaptations due to the heavy resistance training. Moreover, the percentage of fat mass of the hammer throwers which participated in the present study was higher than the one previously reported for lower-lever hammer throwers (Morrow et al., 1982), junior throwers (Thorland et al., 1981), and shot putters (Dickerman et al., 2000; Fahey et al., 1975).

Conclusion

The results of the present study reveals that the main training adaptations of the hammer throwers compared to control individuals is the increased lean body mass and bone mineral density, and the hypertrophy of type IIA muscle fibres in vastus lateralis. Moreover, two points require further investigation: the increased percentage of type IIX muscle fibres in vastus lateralis of these athletes as well as the homogeneity of the percentage of type II muscle fibre area.

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Key points

- Well-trained hammer throwers had increased lean body mass, higher type IIA muscle fibres cross sectional areas, as well as higher bone mineral density, compared to controls.
- Increased lean body mass was closely related with hammer throwing performance.
- The relative high percentage of type IIX muscle fibres in vastus lateralis in hammer throwers warrants further investigation.

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Panagiota MANTA

Employment

Associate Professor**,** Department of Neurology, Eginition Hospital, School of Medicine, University of Athens, Athens, Greece

Degree

MD (Neurologist), PhD

Research interests

Skeletal muscle and function in neuromuscular disorders

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Giorgos GEORGIADIS

Employment

Professor, Department of Track and Field, School of Physical Education and Sport Science, University of Athens, Daphne, Athens, Greece

Degree

PhD

Research interests

Muscular strength and performance in athletic throws

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