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Body Composition and Muscle Characteristics of Division I Track and Field Athletes

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Abstract

The purpose of this study was to evaluate event-specific body composition and muscle characteristics of track and field athletes, and to assess body composition changes after one year. Sixty collegiate track and field athletes (Mean ± SD; Age = 19.2 ± 1.4 yrs, Height = 174.6 ± 9.0 cm, Weight = 71.5 ± 12.5 kg) were stratified into six event groups. Total and regional body composition measurements were assessed using dual-energy x-ray absorptiometry. A panoramic scan of the vastus lateralis was taken with B-mode ultrasound to determine muscle cross sectional area (mCSA) and echo intensity (EI). Body composition measurements were repeated a year later in a subset of returning athletes (n=33). Throwers had significantly more absolute fat mass (FM; 21.6 ± 11.0 kg), total body mass (89.7 ± 17.4 kg), percent fat (23.6 ± 7.8) and trunk fat (9.4 ± 5.8 kg) than all other event groups ($p<0.05$). Throwers had the most absolute lean mass (LM; 64.2 ±11.7 kg; $p>0.05$), but relative to body mass had relatively less LM (0.72 ± 0.08 kg; $p<0.05$). Despite high FM, throwers had lower EI (63.4 ± 5.2 a.u). After one year, relative armLM increased slightly in all event groups ($p<0.05$). Evaluation of muscle characteristics in addition to total and regional body composition may be valuable for improving performance, injury prevention, and assessing health risks. With appropriate training, track and field athletes may be able to minimize losses in LM and gains in FM between seasons.

Keywords

Dual-energy x-ray absorptiometry; ultrasound; muscle cross sectional area; echo intensity

INTRODUCTION

Track and field is comprised of 21 different events, making it the most highly participated in sport by female student athletes and the third most participated in sport for men (17). It is well documented that body composition varies by sport (4, 24), as well as by position, and event within a sport (13, 15, 22). Evaluation of body composition has been previously shown to be an important determinant of health and performance (12), however, little data quantifying body composition characteristics of track and field athletes exists.

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Body composition of track and field athletes is often generalized to characteristics observed in sprinters and jumpers (4, 24) or throwers (9), respectively, with few studies evaluating differences between more specific event groups (13, 22), or across various levels (i.e. Division I vs. II, etc.). Many of the values for specific event groups date back to the 1970's. Since then, athletes have become bigger, stronger, leaner, and more specialized due to the increasing difficulty of reaching elite status (19). Measurement techniques have also become more sophisticated. Past measurements of percent body fat (%fat) and lean mass (LM) in track and field athletes were done with skinfolds and limb circumference measures (13). Newer methods such as dual-energy x-ray absorptiometry (DXA) uses tissue density to assess whole body and regional fat mass (FM), LM, and bone mineral content (BMC). Assessment of body composition using DXA allows for the quantification of segmental measurements, such as arms, legs, and comparing right versus left sides. Segmental measurements are valuable in the characterization of track and field athletes who are looking to improve strength and power in specific muscle groups. Comparing right versus left side is also an effective way to assess athletes for muscle imbalances that could lead to injury. Few studies have tracked body composition in track and field athletes from year to year, which may provide insight into potential adaptations to training. Regular body composition testing of track and field athletes is also an effective way for coaches to track athlete health and monitor their athletes for potential health and injury risks (25).

Recently, ultrasound has been used to evaluate muscle characteristics in athletes (8, 15, 23). Measurements of muscle cross sectional area (mCSA) and echo intensity (EI) can be used to assess muscle size and quality, respectively (2). A larger mCSA has been previously associated with greater muscle strength, which in turn has been linked with enhanced speed and power (5). Muscle quality is a broad measure of the relative amount of connective and adipose tissue within a muscle (1, 18). Lower EI values are indicative of higher muscle quality, which is related to cardiorespiratory fitness (3) and may also be associated with strength and power output (3, 7). In Division I collegiate cross country runners, faster 6K times were associated with relatively lower EI and greater mCSA (23). Muscle size was also strongly related with bone integrity and inversely related with EI, suggesting that improvements in muscle size and quality may be related to improved performance and injury prevention (23). Since the development and maintenance of quality LM is highly important for successful athletic performance, ultrasound measures of muscle characteristics, in combination with body composition, may give coaches a more direct assessment of specific muscle group training adaptations.

Track and field has a high participation rate, with a wide variety of events that each require specialized training and emphasis on specific muscle groups. Success in certain events may favor different body types and body composition characteristics. Therefore, the purpose of this study was to evaluate event-specific body composition and muscle characteristics of division I (DI) collegiate track and field athletes. A secondary purpose was to evaluate changes in body composition in a subset of athletes following one calendar year.

METHODS

EXPERIMENTAL APPROACH TO THE PROBLEM

Body composition testing was completed with National Collegiate Athletic Association (NCAA) Division I varsity track and field athletes at the start of the pre-season training period for two consecutive years (August 2013 and August 2014). Athletes completed one 30-minute testing session. Athletes were asked to fast for two hours, but remain hydrated, and abstain from exercise for at least eight hours prior to testing. Upon arrival, height (Perspective Enterprises, Portage, MI) and weight (Detecto, Webb City, MO, USA) were measured. Dual-energy x-ray absorptiometry was used to determine FM, LM, total body mass (TBM), %fat, arm lean mass (armLM), leg lean mass (legLM), trunk fat (TF) and BMC. Following the DXA scan, a panoramic scan of the vastus lateralis (VL) was taken using B-mode ultrasound. The resulting scan was analyzed using Image-J software (National Institute of Health, USA, Version 1.37) to measure mCSA and EI. Body composition was tested again in returning athletes at the beginning of the 2014 pre-season training period (August 2014) following the same protocol.

SUBJECTS

Sixty male and female NCAA DI collegiate track and field athletes (Mean ± SD; Age = 19.2 ± 1.4 yrs, Height = 174.6 ± 9.0 cm, Weight = 71.5 ± 12.5 kg) volunteered to participate in the study (Table 1). All athletes were currently training and competing for the university. Thirty-three of these athletes were on the team for both the 2013 and 2014 season, creating a subset of athletes who were measured and analyzed across two seasons. All athletes were over the age of 18 and signed an informed consent approved by the University's Institutional Review Board for the protection of human subjects. All athletes, independent of sex, were stratified into six different event groups: sprint/sprint hurdles (sprints), mid-distance/hurdles (midD), heptathletes and decathletes (multis), jumps/high jump (jumps), pole vault/javelin (PV/jav), and throws. Athletes were assigned to event groups based on primary competitive event choice. Event groupings were based on similarities in event type (track vs. field; run vs. jump vs. throw), race distance (short sprint vs. mid-distance), and physical demand (muscle group emphasis). Due to low subject number, javelin athletes were combined with pole vault athletes, based on similarities in upper body demands and physiologic characteristics. Distance runners were evaluated separately in a previous study (23).

PROCEDURES

Body Composition—Body composition was assessed via DXA (Hologic Inc., Bedford, MA, USA; Apex Software Version 3.3). Athletes were asked to arrive fasted, but hydrated, and rested to their testing session wearing only lightweight athletic clothing. Upon arrival, athletes were asked to remove all metal to avoid interference with the DXA scan. Height, weight, ethnicity, sex, and date of birth were entered into the DXA computer. Athletes were asked to lie supine in the middle of the scanning table with all extremities fitting inside of the measuring parameter. If an athlete was taller than the parameter of the scan, they were positioned so that their head was as close to the top of the scan parameter as possible and the ends of their toes were excluded from the scan. DXA test-retest reliability from our laboratory with a similar population are as follows: intraclass correlation coefficient

(ICC)=0.98 and standard error of measure (SEM)=0.85 kg for FM, ICC=0.99 and SEM=1.07 kg for LM, and ICC=0.96 and SEM=1.279% for %fat.

Muscle Characteristics—Using a GE Logiq-e B-mode ultrasound device (GE Healthcare, Wisconsin, USA), mCSA and EI were measured from a panoramic scan of the VL with standardized settings (Frequency: 26 Hz, Gain: 68, Depth: 4.5 cm). Each athlete was asked to lay supine on a table in a relaxed position for approximately three minutes to allow fluid compartments to equalize. A cushion was placed under the right knee to relax the VL and a foam pad was strapped around the midpoint of the right thigh to serve as a guide for the scan. Using a wide-band linear array ultrasound transducer probe (GE: 12L-RS) the thigh was scanned from the lateral VL border to the medial fascia separation. The probe was held perpendicular to the VL and swept across the skin at a constant speed and pressure. Muscle cross sectional area and EI were manually measured offline using Image-J software (National Institute of Health, USA, Version 1.37). Before measurements were performed, each scan was individually calibrated by measuring the number of pixels in a known distance (1 cm). Muscle cross sectional area was measured by outlining the perimeter of the VL along the inside of the fascia border. Echo intensity was determined in the standard histogram function using grayscale analysis of pixels ranging from 0 to 255. Ultrasound assessments of muscle characteristics can vary depending on operator technique, therefore, all scans were analyzed by the same technician. Reliability calculations for mCSA were ICC=0.99 and SEM=0.744 cm^3 and ICC=0.99 and SEM=1.5 a.u. for EI.

Statistical Analyses—Sixty athletes underwent testing during the two year time span. A single measure from each athlete tested was stratified by event group and a one-way analysis of variance (ANOVA) was used to evaluate body composition (FM, LM, %fat, armLM, legLM, TF, BMC) and muscle characteristic differences between event groups. A sub-set of athletes (n=33) underwent body composition testing at both time points (August 2013 and August 2014). Measurements from these returning athletes were used to assess changes in body composition. If baseline variables were significantly different between event groups (legLM, TF, BMC), a one-way analysis of covariance (ANCOVA) was used to evaluate body composition after one year of training, when adjusting for baseline differences. All other body composition variables were evaluated with separate repeated measures ANOVAs [time (fall 2013 vs fall 2014) × event group]. A separate one-way ANOVA was used to evaluate muscle characteristic (mCSA and EI) differences between event groups. When necessary, LSD post hoc comparisons were made to identify significance among groups. As a secondary analysis, a one-way ANOVA was done to evaluate body composition and muscle characteristics between men and women, collapsed across event group. All statistical analyses were completed using SPSS (Version 21, IBM, Armonk, NY, USA), using an α of $p \leq 0.05$ to determine statistical significance.

RESULTS

Body Composition

Body composition measurements for each event group are shown in Table 2. Throwers weighed significantly more (90.4 ± 18.3 kg) than all other event groups (group mean = 70.1

± 10.7 kg; $p<0.05$), while multis weighed more than sprints (mean difference = 10.0 kg; $p=0.047$). Throws had significantly more FM (21.6 ± 11.0 kg), TBM (89.7 ± 17.4 kg), %fat (23.6 ± 7.8) and TF (9.4 ± 5.8 kg) than all other event groups ($p<0.05$). Though not statistically significant, throwers had the greatest amount of LM (64.2 ±11.7 kg) compared to all other event groups (group mean = 54.8 ± 10.0 kg; $p>0.05$). Throwers, multis, and midD all had similar measures of BMC ($p>0.05$), while throwers and multis had greater BMC than other event groups ($p>0.05$). However, all event groups had BMC values that were considered to be within a healthy range as compared to normative data reported by the DXA. Male and female athletes were significantly different in all body composition measures ($p<0.05$; Tables 2 and 3) except for trunk fat ($p=0.055$).

Due to the relationship of body mass and body composition, all body composition variables were divided by total body mass to account for the differences between groups (Table 3). After accounting for body mass, throwers continued to have significantly more relative FM (0.23 ± 0.08 kg) than all other event groups (group mean = 0.16 ± 0.05 kg; $p<0.05$), except for multis (0.18 ± 0.05 kg). Throwers also had significantly more relative TF (0.10 ± 0.04 kg) than all other event groups (group mean = 0.06 ± 0.02 kg). Evaluation of LM demonstrated throwers had significantly less relative LM (0.72 ± 0.08 kg) and legLM (0.25 ± 0.03 kg) compared to all other groups (LM group mean = 0.80 ± 0.05 kg; $p<0.05$; legLM group mean = 0.30 ± 0.02 kg). Pole vault/javelin (0.038 ± 0.002 kg) and throwers (0.037 ± 0.005 kg) had significantly lower relative BMC than all other event groups ($p<0.05$). When evaluating relative changes after one year, only a significant main effect for time for relative armLM was observed, with all event groups showing a slight increase in armLM (Figure 1).

Muscle Characteristics

There were no significant differences in mCSA between event groups ($p=0.594$) (Table 4). When evaluating EI, midD/hurdlers had significantly lower EI (62.4 ± 6.9 a.u.; $p<0.05$) than multis (73.0 ± 5.2 a.u.), jumps (71.0 ± 9.25 a.u.), and pole vault (71.2 ± 12.5 a.u.). Throwers had significantly lower EI (63.4 ± 5.2 a.u.; $p<0.05$) than multis and pole vault. Evaluation of sex differences showed men had significantly greater mCSA (27.2 ± 5.4 cm^2; $p<0.001$) and lower EI values (63.9 ± 5.6 a.u.; $p=0.001$) compared to women (mCSA = 22.0 ± 4.7 cm^2; EI = 71.2 ± 9.4 a.u.).

DISCUSSION

Successful track and field athletes have generally been characterized by certain body composition and muscle characteristics. Sprinters are typically lean and muscular; distance runners are smaller with little body fat, while throwers have the greatest amount of body mass (20). To date, specific quantification of these characteristics is limited. Additionally, while assessment of absolute body composition and muscle characteristics may provide valuable information about characteristics that are associated with success in a particular event, comparison of athletes relative to body mass may give a more accurate comparison when evaluating overall health. The primary findings of the current study demonstrate that in Division I collegiate track and field athletes, throwers had greater FM and TF than all other event groups, even when accounting for body mass, yet had lower relative LM and similar EI values to that of mid distance runners, when accounting for total body mass. Multi-event athletes generally had characteristics between those of throwers and other event groups. Interestingly, all other groups (sprints, midD, jumps, and PV/jav), had similar body composition values. Bone mineral content was above average in all event groups, supporting that weight-bearing exercise can have a positive impact on overall bone health (11). As expected men and women had significantly different total and regional body composition measures. On average, male athletes had more LM and female athletes had more FM and a higher %fat, as would be expected due to inherent physiological differences between men and women. Men also had greater mCSA and lower EI, reflecting the differences in body composition between men and women. For men and women combined, there were few changes in body composition after a year of training, with only armLM increasing across groups.

Results from this study are consistent with past body composition measurements of collegiate track and field athletes. Throwers consistently have greater body mass, FM, and %fat than runners and jumpers (13, 22), which is likely related to the importance of mass for success in throwing events (20). Similar values for all body composition measures were observed in sprinters and jumpers. Both groups are characteristically noted as being muscular with little FM and a lower %fat (4, 20, 24). These events commonly overlap, with athletes participating in both sprinting and jumping events. High overlap in athlete participation would support the common practice of combining these events when evaluating body composition (4, 24). Mid-distance runners also shared similar body composition values as sprinters and jumpers. Though less commonly assessed, Pipes (1977) and Malina et al. (1971) also found mid-distance runners to have similar FM, LM, and %fat values as sprinters and jumpers.

When comparing event groups relative to total body mass, throwers had significantly greater amounts of FM and TF, but interestingly had significantly less relative LM. Using skinfolds and limb circumferences to estimate %fat and muscularity, Malina et al. (1971) observed the difference in arm diameter between throwers and other event groups to be greatly reduced when accounting for subcutaneous fat. Further, when ranked based on estimated relative arm muscularity, sprinters were reported to be the most muscular, followed by jumpers, distance runners and then throwers (13). In the current study, using more sophisticated measures of LM, throwers had similar relative armLM as other event groups, but less relative legLM. Studies looking specifically at the relationship between body composition and performance in elite shot put athletes suggest that performance may be more related to measures of muscle strength and/or power than increased LM (9, 10, 26). The group of throwers analyzed in the current study was comprised of three men and six women, which potentially could lower the average LM, as women had significantly less LM than men. However female throwers still had the greatest absolute LM (58.1 ± 8.0 kg) when compared to other female event groups (group mean = 45.9 kg). Despite having relatively less LM, throwers still had the highest amount of absolute LM (64.2 ± 11.7 kg), as would be advantageous in a power focused event.

In recent years, ultrasound has emerged as a valid method to evaluate muscle characteristics of muscle size and quality (7, 14). When using this technique to evaluate division I football players, Melvin et al. (15) found that while offensive (OL) and defensive linemen (DL) had significantly greater %fat than other positions, they had EI values similar to that of other positions, demonstrating similar muscle quality. Compared to values reported by Melvin et al. (2014), throwers in the current study had similar EI values as football players (range = 54.5 – 65.8 a.u.). Compared to other track and field events, throwers had lower EI values than other event groups despite having a higher %fat and no differences in mCSA. Interestingly, the EI of the VL in throwers was similar to that of midD/hurdles who had significantly lower %fat. The findings of the current study imply that despite greater amounts of FM and relatively lower amounts of LM, throwers may have good muscle quality, and therefore at lower risk for health disease. Muscle size and quality may be related to strength and power (7), but further research is needed to determine if improved muscle characteristics, especially lower EI, are related to better performance. Muscle quality may also be a good indicator for certain health outcomes, as individuals with greater adiposity (27) or certain neuromuscular disorders (21) may be more likely to have greater infiltration of fat and connective tissue within the muscle. Lower EI values, despite high amounts of FM, could indicate that throwers may be at a lower risk for health disease while training and competing, related to protective effects of exercise. However, excess FM could lead to health risks later in life if exercise in not maintained.

In the subset of athletes who were reassessed after a year of training, only a small increase in armLM across all event groups was observed. The increase in armLM may be attributed to better strength programs and greater emphasis on the importance of arm strength in running events at the collegiate level, although this has not been previously evaluated. However, the observed change did not extend beyond the error of the measure of the DXA (1.07 kg), and there is little data available on the relationship between arm strength and sprint performance. Past studies have reported decreases in FM and %fat, increases in LM, and increases in BMD in sprinters and jumpers over the course of a competitive season (4, 24), but few have looked at changes after an entire year. Standforth et al. (2014) tracked athletes over a three year period, taking body composition measures pre and postseason, with no observed changes in body composition in sprinters and jumpers. In the present study, evaluation of changes after an entire year included the offseason, where there is potential for increases in FM and %fat, along with decreases in LM. No significant changes in FM, LM, and %fat were observed in the current study, which may indicate that when given proper training, track and field athletes are able to maintain baseline LM and avoid significant gains in FM, even after an offseason. Evaluation of body composition at multiple time points throughout the track and field season may reveal more profound changes in body composition that occur during the competitive season versus the off-season. Further, ultrasound measures of muscle characteristics may be a more sensitive measure of tracking changes in LM than the DXA (15), providing a qualitative measure for tracking adaptions to training, especially in muscle groups targeted by specific events.

Limitations of the current study should be noted. While evaluation of track and field athletes by event groups allows for more specific athlete characterization and reduces variance that would likely result from broad event group characterizations, this limits the sample size and generalizability of the results. The minimal changes observed after a year of training in the present study may have been influenced by high variability within event groups and small sample size, as there was only one jumps athlete in this sample with repeated body composition measures. Establishing event groupings can be challenging as many track and field athletes compete in multiple events, with some competing in running events and field events. Compilation of measurements from multiple teams would allow for stratification into more specific event groups and for the assessment of men and women separately.

Results from this study may be used in establishing event specific normative values, which may be beneficial in helping to optimize program design. Body composition and muscle characteristic values also allow for an evaluation of training adaptations, overall health status, and potential future injury and health risks. Results from the current study suggest that higher body mass that is common in throwers is a result of both increased FM and LM, with greater deposits in the trunk region. Elevated FM, especially in the trunk, as shown in the current study, may lead to health implications later in life (6), although this is beyond the scope of the current study. Evaluation of muscle characteristics revealed that despite higher amounts of FM, throwers have good muscle quality, which is associated with a positive health status. Minimal changes in body composition after a year of training suggests that when given appropriate training, DI collegiate track and field athletes are able to maintain body composition, without any losses in LM or gains in FM. Tracking body composition changes over an athlete's entire collegiate career may reveal more significant changes in body composition. Further, relationships between body composition and muscle characteristics and their associations with performance should be investigated.

PRACTICAL APPLICATIONS

As athletes become increasingly specialized in their respective events, establishing body composition normative values for specific events could be a valuable tool for coaches and trainers when designing training programs to maximize athlete performance. Regular body composition testing is an effective way for coaches, trainers, and dietitians to monitor athletes for appropriate training adaptations, injury prevention, return from injury, and for potential health risks, such as eating disorders (25). Measuring athletes at the beginning of the season gives coaches and trainers a baseline value for each athlete. These values can be used to quantify physiological adaptations that may occur while in-season and through the off-season as a way to evaluate the effectiveness of a training program and associate with performance. In the event of an injury, having pre-injury body composition and muscle characteristic values may help facilitate rehabilitation programs to quicken return to play. The use of ultrasound to assess muscle characteristics in combination with body composition may provide a more direct measure of muscle size and quality which is of interest in high level athletes. Ultrasound may also may also be more sensitive to changes in LM compared to the DXA (16) which is beneficial for assessing positive gains in response to training or negative responses due to injury or poor diet.

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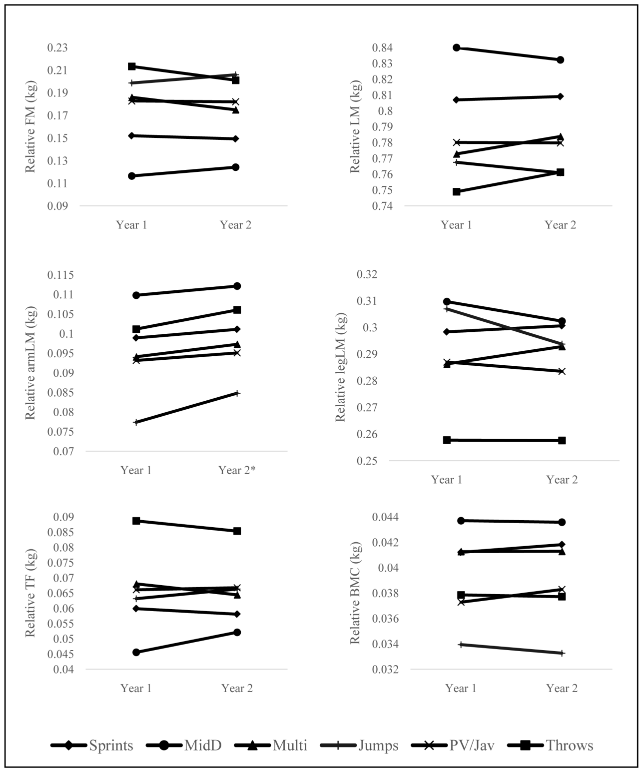

* Indicates a main effect for time (p = 0.002)

Figure 1.
Year 1 to Year 2 comparison of body composition measures in a subset of returning athletes (n=33)

Table 1

Track and field athlete demographics stratified by event (Mean ± SD)

	N	Age (yrs)	Height (cm)	Weight (kg)
All Athletes	60	19.2 ± 1.4	174.6 ± 9.0	72.8 ± 14.0
Men	31	19.5 ± 1.7	180.3 ± 7.4	78.4 ± 11.6
Women	29	18.9 ± 1.1	168.5 ± 6.2[#]	67.0 ± 14.2[#]
Sprints	17	19.0 ± 1.0	172.2 ± 9.4	67.1 ± 8.8[*]
MidD	9	19.2 ± 1.3	172.7 ± 5.2	70.9 ± 8.0[*]
Multis	9	19.8 ± 1.2	180.9 ± 10.1	77.0 ± 14.3
Jumps	7	19.0 ± 1.3	173.4 ± 9.6	67.6 ± 9.1[*]
PV/Javelin	9	19.6 ± 2.7	173.7 ± 9.2	68.1 ± 11.9[*]
Throws	9	18.9 ± 0.8	176.4± 8.6	90.4 ± 18.3

[#]Significantly different from men

[*]Significantly different from throws

Table 2

Absolute body composition values (Mean ± SD) by event group

	Sprints	MidD	Multis	Jumps	PV/Javelin	Throws	Men	Women
Weight (kg)	67.1 ± 8.8[*a]	70.9 ± 8.0[*]	77.0 ± 14.3[*]	67.6 ± 9.1[*]	68.1 ± 11.9[*]	90.4 ± 18.3	78.4 ± 11.6	67.0 ± 14.2[#]
FM (kg)	10.1 ± 2.0[*]	10.8 ± 5.1[*]	13.7 ± 3.0[*]	10.45 ± 1.4[*]	11.7 ± 1.6[*]	21.6 ± 11.0	10.5 ± 3.1	15.1 ± 7.7[#]
LM (kg)	53.3 ± 9.0	56.3 ± 7.7	59.1 ± 13.3	53.4 ± 9.3	53.0 ± 11.6	64.2 ± 11.7	63.5 ± 8.4	48.5 ± 6.8[#]
Total Mass (kg)	66.1 ± 8.6[*a]	70.0 ± 7.9[*]	75.9 ± 13.8[*]	65.8 ± 8.3[*]	67.2 ± 11.8[*]	89.7 ± 17.4	77.0 ± 11.5	66.3 ± 14.0[#]
%fat	15.6 ± 4.1[*]	15.4 ± 6.7[*]	18.5 ± 4.8[*]	16.1 ± 3.7[*]	17.8 ± 4.1[*]	23.6 ± 7.8	13.5 ± 2.1	22.0 ± 5.3[#]
ArmLM (kg)	6.5 ± 1.8	7.1 ± 1.4	7.2 ± 2.5	6.5 ± 1.9	6.5 ± 2.0	8.0 ± 2.4	8.5 ± 1.4	5.3 ± 0.8[#]
LegLM (kg)	19.9 ± 3.0	21.1 ± 2.4	21.8 ± 4.5	19.8 ± 3.0	19.4 ± 4.0	21.9 ± 3.9	23.0 ± 2.7	18.0 ± 1.9[#]
TF (kg)	4.0 ± 0.8[*]	4.2 ± 2.1[*]	5.1 ± 1.2[*]	3.9 ± 0.4[*]	4.4 ± 0.8[*]	9.4 ± 5.8	4.3 ± 1.4	5.8 ± 4.0
BMC (kg)	2.7 ± 0.5[*a]	2.9 ± 0.5	3.1 ± 0.6	2.7 ± 0.5[*]	2.5 ± 0.4[*a]	3.3 ± 0.5	3.2 ± 0.5	2.5 ± 0.4[#]

[*] Significantly different from thrower

[a] Significantly different from multi

[#] Significantly different from men

Table 3

Relative body composition values (Mean ± SD) by event group

	Sprints	MidD	Multis	Jumps	PV/Javelin	Throws	Men	Women
FM (kg)	0.16 ± 0.04 *	0.15 ± 0.07 *	0.18 ± 0.05	0.16 ± 0.04 *	0.18 ± 0.04 *	0.23 ± 0.08	0.13 ± 0.02	0.22 ± 0.05 #
LM (kg)	0.80 ± 0.04 *	0.81 ± 0.06 *	0.77 ± 0.05 *	0.81 ± 0.05 *	0.78 ± 0.04 *	0.72 ± 0.08	0.83 ± 0.02	0.74 ± 0.05 #
ArmLM (kg)	0.10 ± 0.02	0.10 ± 0.02	0.09 ± 0.02	0.10 ± 0.02	0.10 ± .01	0.09 ± 0.02	0.11 ± 0.01	0.08 ± 0.01 #
LegLM (kg)	0.30 ± 0.02 *	0.30 ± 0.02 *	0.30 ± 0.02 *	0.3 ± 0.02 *	0.3 ± 0.02 *	0.25 ± 0.03	0.30 ± 0.02	0.28 ± 0.03 #
TF (kg)	0.06 ± 0.02 *	0.06 ± 0.03 *	0.07 ± 0.02 *	0.06 ± 0.01 *	0.07 ± 0.01 *	0.10 ± 0.04	0.06 ± 0.01	0.08 ± 0.03 #
BMC(kg)	0.040 ± 0.003 *β	0.041 ± 0.004 *β	0.042 ± 0.002 *β	0.041 ± 0.004 *β	0.036 ± 0.002	0.036 ± 0.005	0.040 ± 0.003	0.040 ± 0.004 #

* Significantly different from throwers

β Significantly different from pole vault/javelin

Significantly different from men

Table 4

Muscle characteristic values (mean ± SD) by event group

	Sprints	MidD	Multis	Jumps	PV/Javelin	Throws	Men	Women
mCSA (cm^2)	24.6 ± 6.0	27.2 ± 6.2	23.1 ± 4.8	24.1 ± 5.5	22.6 ± 4.7	25.8 ± 6.7	27.2 ± 5.4	22.0 ± 4.7[#]
EI (a.u.)	66.4 ± 7.2	62.4 ± 6.9	73.0 ± 5.2[*ξ]	71.0 ± 9.3[ξ]	71.2 ± 12.5[*ξ]	63.4 ± 5.2	63.9 ± 5.6	71.2 ± 9.4[#]

[*] Significantly different from throws

[ξ] Significantly different from midD/hurdles

[#] Significantly different from men