Relationship of The Knee Extensor Strength But Not The Quadriceps Femoris Muscularity With Sprint Performance in Sprinters: A Reexamination and Extension

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Abstract

Purpose: This study examined the relationships of the knee extensor strength and quadriceps femoris size with sprint performance in sprinters.

Methods: Fifty-eight male sprinters and 40 body size-matched male non-sprinters participated in this study. The knee extensor isometric and isokinetic strengths were measured using a dynamometer. The isokinetic strength measurements were performed with slow and fast velocities at 60°/s and 180°/s, respectively. The quadriceps femoris muscle volume (MV) was measured using magnetic resonance imaging. The relative values of the knee extensor strengths and quadriceps femoris MV were normalized to body mass.

Results: The absolute and relative values of the two velocity isokinetic strengths, but not of isometric strength, of the knee extension were significantly higher in sprinters than in non-sprinters (both *P*s < 0.05). Such a significant difference was also observed for the relative quadriceps femoris MV ($P = 0.018$). In sprinters, there were significant correlations between all three knee extensor strengths and quadriceps femoris MV ($r = 0.421$ to 0.531, all *P*s £ 0.001). The absolute and relative strengths of the fast-velocity isokinetic knee extension correlated with personal best 100-m sprint time ($r = -0.477$ and -0.409, respectively, both *P*s £ 0.001). By contrast, no significant correlations were observed between absolute and relative quadriceps femoris MVs and personal best 100-m sprint time.

Conclusions: These findings suggest that despite the presence of the relationship between muscle strength and size, the knee extensor strength may be related to superior sprint performance in sprinters independently of the quadriceps femoris muscularity.

Background

Superior sprint performance is achieved using gross torques of the lower limb joints [1–3]. Of the joint torques, the knee extensor joint torque is known to be a major source for performing the rapid and strong knee extension during the swing phase while sprinting [1–3]. Furthermore, the knee extensor torque contributes to accelerating the center of mass of the body and maintaining the height of the center of mass of the body during the stance phase while sprinting [1–3]. These roles of the knee extensor torque help increasing peak vertical ground reaction forces during sprinting [1–3], which is a major determinant of sprint performance [4, 5]. Therefore, the knee extensor torque may play an important role in achieving superior sprint performance in sprinters.

The knee extensor muscle strength (i.e., joint torque) is known to be a major factor for determining sprint performance in athletes [6–9], including sprinters [6, 7]. Several previous studies reported a positive correlation between isokinetic knee extensor strength and sprint performance in sprinters [6, 7]; however, further understanding of this relationship has not progressed in recent years. The magnitude of the muscle strength, including isokinetic strength, of the knee extensors is primarily determined by agonist quadriceps femoris size in untrained participants [10–12]; however, to the best of our knowledge, no

study has examined such a relationship in sprinters. Despite this theoretical relationship, we and others previously determined no correlation between quadriceps femoris size and sprint performance in sprinters [13, 14]. Based on the findings of our and other previous studies, it is hypothesized that the knee extensor strength would be related to sprint performance in sprinters independently of the quadriceps femoris muscularity; however, this hypothesis has not been clarified yet. To test this hypothesis, we first compared the knee extensor strength and quadriceps femoris size in sprinters and non-sprinters in order to understand the features of these variables in sprinters. Second, we examined the relationship between knee extensor strength and quadriceps femoris size in sprinters. Third, we examined the relationships of the knee extensor torque and quadriceps femoris size with 100-m sprint performance in sprinters.

Methods

Participants

Fifty-eight male well-trained sprinters (age: 21 ± 2 years) participated in this study. Their best official record of a 100-m race (i.e., personal best 100-m sprint time) ranged from 10.32 to 11.80 sec (mean, 11.13 ± 0.36 sec) within the previous one year. They were involved in regular sprint training at least 5 times per week and had regularly competition. In addition, 40 non-sprinters (age: 22 ± 2 years) participated as a control group. Their physical characteristics (i.e., body height and body mass) were similar to those of the sprinters (see **Table 1**). The body size-matched control participants were recreationally active, but were not involved in any specific physical training program within the previous three years. Nevertheless, many of them had participated in recreational sports and/or physical training for 2-3 hours per week. All subjects were informed of the experimental procedures and risks and provided their written informed consent prior to the participation in the study. The study was performed in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Ritsumeikan University (BKC-IRB-2016-047).

Knee extensor strength

The method for measuring the knee extensor strength has been described in our previous studies [11, 12, 15, 16]. The isometric and isokinetic knee extensor strengths of the right leg were measured using a dynamometer (BIODEX system 3; BIODEX Medical, Shirley, NY, USA). The hip and thigh of participants were securely fixed by seat belts. The hip and knee joint angles were fixed at 100 ° and 90 ° (full extension was at 180 °), respectively. The ankle joint was attached to a bar connected to the force transducer. Isometric strength measurement was performed at a 90º of the knee joint, which was selected according to our and other previous studies [10-12, 15, 16]. Isokinetic strength measurements were performed with slow and fast angular velocities at 60º/s and 180º/s, respectively, through a 90º to 170º range of motion of the knee joint. Both angular velocities employed in the isokinetic strength measurements were selected according to our and other previous studies [12, 17]. The isometric and isokinetic strength measurements were performed with two trials, or more than two trials. The isometric strength trials were performed for 3 sec each with a 1-min rest period. The isokinetic strength trials were performed consecutively with 3

repetitions per each trial. The rest intervals between the trials were set for 1 min. If the difference between the two strength values of each strength measurement was more than 5 % of the highest value, additional trials were performed until this was corrected, as our previous studies [11, 12, 15, 16]. The highest value of the two trials, or more than two trials, for each strength measurement was used for analyses. The reproducibility of the knee extensor strength measurement has been described in our previous studies [12, 15].

Quadriceps femoris size

The method for measuring the quadriceps femoris size has been described in our previous studies [11-13]. The quadriceps femoris size was measured using a 1.5-T magnetic resonance system (Signa HDxt; GE Medical Systems, WI, USA). Participants were placed in a supine position on the scanner bed, with both knees fully extended and both ankles set at the neutral position (i.e., 0°). To measure the quadriceps femoris size, axial T_1-weighted scans of the thigh of the right leg were acquired with a standard body coil. The axial scans were obtained in successive slices with an inter distance of 10 mm from the inferior aspect of the greater trochanter to the lower edge of the femur with a repetition time of 600 ms, echo time of 7.6 ms, field of view of 480 mm, and matrix size of 512 × 256 pixels.

Analyses of cross-sectional area (CSA) and MV of the quadriceps femoris were conducted using image analysis software (OsiriX Version 5.6, Switzerland). The CSAs of the quadriceps femoris were calculated from three regions at proximal 25% (i.e., proximal CSA), 50% (i.e., middle CSA), and 75% (i.e., distal CSA) along their length. The MV of the quadriceps femoris was calculated by multiplying the sum of CSAs along their length at intervals of 10 mm. The reproducibility of the quadriceps femoris size measurement has been described in our previous studies [13].

Statistical analysis

Data are presented as mean ± stander division. Comparisons of measured variables between sprinters and non-sprinters were performed using an unpaired *t*-test. The Cohen's *d* effect size using the pooled standard division was calculated to determine the magnitude of the difference in the variable between the two groups [18]. This effect size was interpreted as small (0.20-0.49), medium (0.50-0.79) and large (> 0.80). Relationships between knee extensor strength and quadriceps femoris size variables in sprinters and non-sprinters were evaluated using a Pearson's product moment correlation. The same statistics was also performed to determine the relationships of knee extensor strength and quadriceps femoris size variables with personal best 100-m sprint time in sprinters. Partial correlation analyses were used to adjust the effects of confounding factors physical characteristics (i.e., body height and mass) or quadriceps femoris size variables (i.e., quadriceps femoris CSAs and MV) on a correlation between the fast-velocity knee extensor strength and personal best 100-m sprint time in sprinters. A stepwise multiple regression analysis was used to determine the predictive variables for the personal best 100-m sprint time of sprinters using physical characteristics (i.e., body height and mass) and all absolute and relative values of the knee extensor strength and quadriceps femoris size variables as independent variables. The

level of statistical significance was defined at $P < 0.05$. All statistical analyses were conducted using SPSS software (version 19.0; IBM Corp, Armonk, NY, USA).

Results

Physical characteristics, knee extensor strength and quadriceps femoris size variables in sprinters and non-sprinters are summarized in **Table 1**. Body height and mass did not differ significantly between sprinters and non-sprinters (both *P*s > 0.05, $d = 0.20$ and 0.08, respectively).

With regard to the knee extensor strength, fast- and slow-velocity isokinetic strengths, but not isometric strength, of the knee extension were significantly higher in sprinters than in non-sprinters (both *P*s < 0.05, $d = 0.41$ and 0.60, respectively). Furthermore, relative values of the fast- and slow-velocity knee extensor isokinetic strengths were significantly higher in sprinters than in non-sprinters (both *P*s < 0.05, $d = 0.50$ and 0.69, respectively). A trend against such significance was also observed for relative isometric knee extensor strength ($P = 0.05$, $d = 0.41$).

With regard to the quadriceps femoris size, proximal CSA, but not middle and distal CSAs, of the quadriceps femoris was significantly greater in sprinters than in non-sprinters ($P < 0.001$, $d = 0.61$). A trend against such significance was also observed for the MV of the quadriceps femoris ($P = 0.080$, $d = 0.36$). Furthermore, relative values of the proximal CSA and MV of the quadriceps femoris were significantly greater in sprinters than in non-sprinters (both *P*s < 0.05, $d = 0.68$ and 0.53, respectively).

Correlation coefficients between knee extensor strength and quadriceps femoris size variables in sprinters and non-sprinters are shown in **Table 2**. In sprinters, significant correlations were observed between most variables of knee extensor strength and quadriceps femoris size ($r = 0.339$ to 0.531, all *P*s < 0.01), excluding a correlation between fast-velocity isokinetic knee extensor strength and proximal quadriceps femoris CSA ($r = 0.186$, $P = 0.163$). Similar trends of correlations between knee extensor strength and quadriceps femoris size variables were observed for non-sprinters (see **Table 2**).

Correlation coefficients of knee extensor strength and quadriceps femoris size variables with personal best 100-m sprint time in sprinters are shown in **Table 3**. Fast-velocity isokinetic knee extensor strength correlated significantly with personal best 100-m sprint time ($r = -0.477$, $P < 0.001$). A similar result was also observed between relative fast-velocity isokinetic knee extension strength and personal best 100-m sprint time ($r = -0.409$, $P = 0.001$). By contrast, there were no significant correlations of absolute and relative values of isometric and slow-velocity isokinetic knee extensor strengths with personal best 100-m sprint time ($r = -0.236$ to 0.083, all *P*s > 0.05). Furthermore, although middle quadriceps femoris CSA showed a trend against significance correlation with personal best 100-m sprint time ($r = -0.226$, $P = 0.088$), no significant correlations were observed between all other quadriceps femoris size variables and personal best 100-m sprint time ($r = -0.226$ to 0.164, all *P*s > 0.05).

A partial correlation analysis revealed that a correlation between fast-velocity isokinetic knee extensor strength and personal best 100-m sprint time remained significant after adjusting for both body height

and mass, (partial r = -0.394, P = 0.003). A significant partial correlation was also observed after adjusting for all quadriceps femoris size variables (partial r = -0.410, P = 0.002) In addition, a stepwise multiple regression analysis revealed that absolute fast-velocity isokinetic strength and relative isometric strength of the knee extension were selected as predictive variables for the personal best 100-m sprint time of sprinters (adjusted R^2 = 0.291, P < 0.001), and the former was the most predictive variable for the sprint performance (b = -0.606, P < 0.001).

Discussion

Prior to this study, the relationship between knee extensor strength and sprint performance with relations to quadriceps femoris size in sprinters had not been explored. In the results of this study, we determined that higher absolute and relative values of fast-velocity isokinetic knee extensor strength correlated significantly with better personal best 100-m sprint time in sprinters. By contrast, despite significant correlations between knee extensor strength and quadriceps femoris size variables, all quadriceps femoris size variables did not correlate significantly with personal best 100-m sprint time. Moreover, partial correlation analyses revealed that, after adjusting for physical characteristics or all quadriceps femoris size variables, a correlation between absolute fast-velocity isokinetic knee extensor strength and personal best 100-m sprint time remained significant. Furthermore, a stepwise multiple regression analysis revealed that the fast-velocity isokinetic knee extensor strength was the most predictive variable for the personal best 100-m sprint time. These present findings suggest that the knee extensor strength may be related to 100-m sprint performance in sprinters. Therefore, this study is the first to determine the relationship between knee extensor strength and sprint performance in sprinters independently of the quadriceps femoris muscularity.

Alexander et al. [6] reported that higher fast-velocity (i.e., 230 º/s) isokinetic knee extensor strength correlated with better personal best 100-m sprint time in 14 male sprinters. Following their study, Dowson et al. [7] also reported positive correlations between absolute and relative values of three velocity isokinetic knee extensor strength and 15-m sprint velocity in 24 male athletes, including 8 sprinters, and these correlations were stronger with fast-velocity (i.e., 150 and 240 º/s) than with slow-velocity (i.e., 60 º/s). Using multiple regression analyses, the two previous studies further reported that the fast-velocity isokinetic knee extensor strength was one of predictive variables for the sprint performances. Nevertheless, these previous studies examined with small sample sizes of sprinters. In the present study, we determined that higher absolute and relative values of fast-velocity isokinetic contraction (i.e., 180 º/s), but not of isometric and slow-velocity isokinetic contractions, of the knee extension correlated significantly with better personal best 100-m sprint time in 58 sprinters. Furthermore, using a stepwise multiple regression analysis, we demonstrated that higher absolute fast-velocity knee extensor strength was the most predictive variable for better personal best 100-m sprint time of the sprinters. Therefore, with a relatively large sample size of sprinters, the present findings corroborate the results in the previous studies [6, 7].

Using ultrasonography (US), Kumagai et al. [19] reported that muscle thickness (MT) of the anterior thigh (i.e., the quadriceps femoris) was larger in higher-level sprinters with personal best 100-m sprint times of < 11.00 sec than in lower-level sprinters with persona best 100-m sprint times of > 11.00 sec. Moreover, Monte and Zamparo [20] reported that US-measured larger MTs of the quadriceps femoris muscles correlated with better personal best 100-m sprint time in sprinters. Kubo et al. [21] also reported such a positive correlation between US-measured quadriceps femoris MT and personal best 100-m sprint time in sprinters. Nevertheless, magnetic resonance imaging (MRI) is known to be a more appropriate apparatus to measure muscle size than US [22, 23]. Using MRI, our previous study determined that the mid-thigh CSA of the quadriceps femoris did not correlate with personal best 100-m sprint time in 32 sprinters [13]. Furthermore, Sugisaki et al. [14] analyzed MRI-measured MV, which is the most appropriate marker of muscle size [22, 24], and reported no correlation between quadriceps femoris MV and personal best 100-m sprint time in 31 sprinters. In the present study, using MRI, we determined that although a trend against significance correlation was observed between middle quadriceps femoris CSA and personal best 100-m sprint time, MV and other region CSAs (i.e., proximal and distal CSAs) of the quadriceps femoris did not correlate with personal best 100-m sprint time in a relative large sample size of sprinters. Therefore, the present findings corroborate the results of our and other previous studies [13, 14]. Altogether, we suggest that greater quadriceps femoris may not be an essential morphological factor for achieving better 100-m sprint performance in sprinters.

This study determined that, despite significant correlations were observed between knee extensor strength and quadriceps femoris size variables, the knee extensor strength, but not the quadriceps femoris size, was related to personal best 100-m sprint time in sprinters. Thus, the present findings suggest the presence of the morphological factor other than the quadriceps femoris size to regulate the knee extensor strength in sprinters. We previously determined that the knee extensor moment arm (MA) correlated with personal best 100-m sprint time in sprinters [13]. Because muscle strength (i.e., joint torque) is theoretically expressed as the product of muscle force and MA dimension, the magnitude of the knee extensor strength is determined not only by the quadriceps femoris size but also by the knee extensor MA. Indeed, we and others previously reported a positive correlation between muscle strength and MA dimension of the knee extensors in untrained participants [10-12]; however, no study has examined such a relationship in sprinters. If this relationship is observed for sprinters, it may help our understanding of the present findings that higher knee extensor strength was related to better 100-m sprint performance, potentially by enhancing knee extensor joint torque while sprinting, which is attributed to greater knee extensor MA rather than quadriceps femoris size.

In the present finding based on the comparison between sprinters and non-sprinters, we found that absolute and relative values of two velocity isokinetic knee extensor strengths were significantly higher in sprinters than in body size-matched non-sprinters, whereas no such significant differences were observed for those of isometric knee extensor strength. Thus, sprinters may be specifically characterized by higher isokinetic strength, but not isometric strength, of the knee extensors. This may be simply because sprint training is performed with dynamic movements. In addition to this reason, the fascicles of the lower limb muscles are known to be longer in sprinters than in untrained participants [25]. Drazan et al. [26] reported

that longer muscle fascicle of the gastrocnemius medialis correlated significantly with higher isokinetic plantar flexor strength in untrained participants, whereas a correlation between the gastrocnemius medialis muscle fascicle length and isometric plantar flexor strength was only a trend against significance. Furthermore, Blazevich et al. [10] reported that muscle fascicle length of the quadriceps vastus lateralis was one of the positive predictive variables for the fast-velocity isokinetic strength, but not isometric and slow-velocity isokinetic strengths, of the knee extensors. In the present study, effect sizes of the differences in two velocity isokinetic knee extensor strengths between sprinters and non-sprinters were relatively larger with fast-velocity than with slow-velocity (i.e., 0.60 [medium effect size] and 0.41 [small effect size], respectively). Therefore, the higher isokinetic knee extensor strengths, especially with fast-velocity, of sprinters may be attributed to their longer muscle fascicles of the quadriceps femoris. Additionally, because positive correlations between the fascicle lengths of the quadriceps femoris muscles and sprint performance have been observed in previous studies [19, 20], the features of the longer quadriceps femoris muscle fascicles in addition to the greater knee extensor MA of sprinters may contribute to interpret the relationship between fast-velocity isokinetic knee extensor strength and 100-m sprint performance obtained in the present study.

Kubo et al. [21] reported that MT of the anterior thigh did not differ between sprinters and body size-matched non-sprinters. Our previous study also reported that no difference for the mid-thigh quadriceps femoris CSA between sprinters and body size-matched non-sprinters [13]. By contrast, in the present study, we found a trend against significance with a greater quadriceps femoris MV in sprinters than that in body size-matched non-sprinters. Furthermore, the relative quadriceps femoris MV was significantly greater in sprinters than in non-sprinters. This might be mainly because of a greater proximal quadriceps femoris CSA in sprinters than that in non-sprinters. Abe et al. [25] reported that MTs at the proximal and middle regions of the anterior thigh were greater in sprinters than in non-sprinters; however, they recruited sprinters with a greater body size than non-sprinters. Ema et al. [27] reported that although relative quadriceps femoris MV normalized to body mass did not differ between sprinters and body size-matched non-sprinters, the relative MV of the rectus femoris, but not of other three quadriceps femoris muscles, was greater in sprinters than in non-sprinters. Composition of the rectus femoris CSA relative to a total of the four quadriceps femoris CSAs is higher at the proximal region than at the middle and distal regions [28]. Therefore, greater MV and proximal CSA of the quadriceps femoris in sprinters than those in non-sprinters observed in the present study may be attributed to a specific hypertrophy of the rectus femoris among the quadriceps femoris in sprinters.

Although we determined a positive correlation between fast-velocity isokinetic knee extensor strength and personal best 100-m sprint time in sprinters, we did not evaluate biomechanical data during 100-m sprinting, which is a major limitation of this study. Thus, our findings cannot explain in detail the potential impact of the higher knee extensor strength on 100-m sprint performance. The higher knee extensor strength appears to help increasing peak vertical ground reaction force during the stance phase while 100-m sprinting [1-3]. The increased peak vertical ground reaction force contributes to shortening contact time and increasing step frequency [1, 4]. These kinetic and kinematic variables are important biomechanical determinants in achieving superior 100-m sprint performance [4, 5]. To further clarify the

present findings, further studies are needed to examine whether higher knee extensor strength would be related to better kinetic and/or kinematic variables during 100-m sprinting in sprinters.

Conclusion

This study demonstrated that despite the presence of the relationship between knee extensor strength and quadriceps femoris size, higher fast-velocity isokinetic knee extensor strength correlated with better personal best 100-m sprint time in sprinters, whereas no such correlation was observed for the quadriceps femoris size. These findings suggest that the knee extensor strength, but not the quadriceps femoris muscularity, may be an important factor of superior 100-m sprint performance in sprinters.

Abbreviations

CSA: cross-sectional area; MA: moment arm; MRI: magnetic resonance imaging; MT: muscle thickness; MV: muscle volume; US: ultrasonography

Declarations

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Authors’ contribution

MH and TS conceived and designed the experiment; MH TS MT TT YK and MO performed experiments; MH and TS analyzed data; MH TS MT YT YK MO AN and TI interpreted results of experiments; MH and TS wrote the manuscript; MT MO AN and TI edited and revised manuscript. All authors have read and approved the manuscript.

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Availability of data and materials

Data will be provided the corresponding author upon request.

Ethics approval and consent to participate

This study was performed in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Ritsumeikan University. All participants were informed of the experimental procedures and risks and provided their written informed consent prior to the participation in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Tables

Table 1. Physical characteristics, knee extensor strength and quadriceps femoris size variables in sprinters and non-sprinters

	Sprinters	Non-sprinters	*P* value	Cohen's *d*
Body height, cm	175.2 ± 5.4	174.1 ± 5.5	0.326	0.20
Body mass, kg	65.4 ± 6.1	65.9 ± 7.0	0.709	0.08
Knee extensor strength				
Isometric strength, Nm	272.9 ± 52.0	257.5 ± 47.5	0.140	0.31
Isokinetic strength at 60º/s, Nm	189.1 ± 38.8	173.8 ± 34.5	0.047	0.41
Isokinetic strength at 180º/s, Nm	128.0 ± 27.5	112.5 ± 23.2	<0.001	0.60
Relative knee extensor strength				
Isometric strength, Nm/kg	4.16 ± 0.62	3.91 ± 0.62	0.050	0.41
Isokinetic strength at 60º/s, Nm/kg	2.88 ± 0.46	2.64 ± 0.50	0.017	0.50
Isokinetic strength at 180º/s, Nmkg	1.95 ± 0.35	1.71 ± 0.35	<0.001	0.69
Quadriceps femoris size				
Proximal CSA, cm^2	53.8 ± 7.0	49.3 ± 8.1	<0.001	0.61
Middle CSA, cm^2	79.0 ± 8.4	77.5 ± 10.6	0.443	0.19
Distal CSA, cm^2	58.2 ± 6.5	58.0 ± 9.1	0.923	0.02
MV, cm^3	2101.5 ± 250.1	2007.4 ± 270.1	0.080	0.36
Relative quadriceps femoris size				
Proximal CSA, $cm^2/kg^{2/3}$	3.32 ± 0.38	3.03 ± 0.49	0.001	0.68
Middle CSA, $cm^2.kg^{2/3}$	4.87 ± 0.39	4.75 ± 0.53	0.241	0.26
Distal CSA, $cm^2/kg^{2/3}$	3.59 ± 0.32	3.56 ± 0.48	0.731	0.08
MV, cm^3/kg	32.1 ± 2.7	30.5 ± 3.5	0.018	0.53

Values are presented as mean ± standard division. CSA: cross-sectional area, MV: muscle volume. Relative values of knee extensor strength and quadriceps femoris size variables were calculated by normalizing to body mass.

Table 2. Correlation coefficients between knee extensor strength and quadriceps femoris size variables in sprinters and non-sprinters

	Isometric strength		Isokinetic strength at 60º/s		Isokinetic strength at 180º/s	
	r	*P* value	*r*	*P* value	*r*	*P* value
Sprinters						
Proximal CSA	0.340	0.009	0.339	0.009	0.186	0.163
Middle CSA	0.450	<0.001	0.523	<0.001	0.518	<0.001
Distal CSA	0.381	0.003	0.463	<0.001	0.451	<0.001
MV	0.491	<0.001	0.531	<0.001	0.421	0.001
Non-sprinters						
Proximal CSA	0.290	0.070	0.193	0.234	0.196	0.225
Middle CSA	0.577	<0.001	0.549	<0.001	0.515	0.001
Distal CSA	0.585	<0.001	0.468	0.002	0.348	0.028
MV	0.637	<0.001	0.520	0.001	0.453	0.003

Table 3. Correlation coefficients of knee extensor strength and quadriceps femoris size variables with personal best 100-m sprint time in sprinters

	r	*P* value
Knee extensor strength		
Isometric strength	-0.076	0.571
Isokinetic strength at 60º/s	-0.236	0.075
Isokinetic strength at 180º/s	-0.477	<0.001
Relative knee extensor strength		
Isometric strength	0.083	0.534
Isokinetic strength at 60º/s	-0.129	0.335
Isokinetic strength at 180º/s	-0.409	0.001
Quadriceps femoris size		
Proximal CSA	0.010	0.942
Middle CSA	-0.226	0.088
Distal CSA	-0.160	0.230
MV	-0.118	0.378
Relative quadriceps femoris size		
Proximal CSA	0.164	0.219
Middle CSA	-0.065	0.629
Distal CSA	0.007	0.956
MV	0.162	0.224