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RESEARCH REPORT

Relationship between the duration of taekwondo training and lower limb muscle strength in adolescents

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KEYWORDS
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Abstract Previous studies have suggested that different durations of taekwondo (TKD) training may result in different lower limb muscle strengths. The objective of this study was to explore the relationship between the duration of TKD training (i.e., number of hours spent training per week) and lower limb muscle strength (at both fast and slow testing speeds) in adolescents. Isokinetic concentric knee and ankle muscle strengths were measured in 20 TKD practitioners (mean age: 15.8 years) at two different speeds (60°/second and 240°/second). Pearson's correlation coefficient (two-tailed) showed that the number of TKD training hours per week was positively correlated with the peak torque of the knee extensors ($r = 0.639$, $p = 0.002$) and knee flexors ($r = 0.472$, $p = 0.036$) at 240°/second. This study did not show any significant correlation between TKD training duration and the peak torque of the knee flexors and extensors at slower speeds (60°/second) or the ankle plantar flexors at any speed. Our results support the notion that the more time one spends in TKD training the greater the muscle strength one could gain and that any subsequent improvements in knee muscle strength is velocity specific. Further study is needed to confirm the optimal amount of training and training parameters required to develop knee muscle strength in TKD athletes.

Introduction

Taekwondo (TKD), a Korean martial art, emphasizes the use of fast spinning kicks. It is one of the most popular martial arts sports in the world [1]. A current review shows that TKD training may improve some aspects of physical fitness, such as flexibility and muscle strength [2]. Among these aspects of fitness, muscle strength of the lower limbs is particularly important because it is essential for kicking, jumping and maintaining postural stability [2]. Indeed, lower limb muscle strength has been reported as crucial for optimal TKD performance [3].

Kinetic analysis of the high front kick, which is a common offensive technique in TKD, shows that vastus lateralis, rectus femoris, biceps femoris and gastrocnemius are

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activated at different times during the execution of this kicking technique; however, the gluteus maximus remains electrically silent in the kicking leg. The authors proposed that the knee extensor muscles are important for the powerful knee extension of the kicking leg while the knee flexors muscles are activated to prevent hyperextension of the knee joint at the end of the extension of the knee [4]. Moreover, TKD training involves explosive jump kicks and shuffling footwork that require strong, powerful calf muscles [5,6]. It is logical to hypothesize that the knee extensor, knee flexor and calf muscles are strengthened by TKD training.

A number of cross-sectional studies have partially confirmed that TKD training can improve knee and calf muscle strength in athletes at different levels of training [2,7—9]. For example, Heller et al [7] reported that the isometric muscle strength of the knee extensors and explosive leg power are above normal in elite TKD athletes. In addition, semiprofessional TKD athletes who are at the black belt level also demonstrate greater knee muscle strength than TKD novices. Furthermore, recreational athletes may also benefit from TKD training. O'Donovan et al [8] found that recreational martial arts practitioners (their study included eight TKD and five Chinese martial arts practitioners) could generate greater isokinetic peak torque than the control group during knee flexion and extension at speeds of 30°/second, 90°/second and 210°/second. Pieter et al [9] also found higher values of isokinetic peak torque during knee flexion at speeds of 120°/second, 180°/second and 250°/second in young recreational TKD athletes. These studies show that TKD athletes at different training levels and durations, including elite athletes (who participate in long periods of high-level training), semiprofessional athletes (long periods of medium-level training) and recreational athletes (short periods of low-level training), may all have greater lower limb muscle strength (i.e., isokinetic testing speeds ranged from 30° to 250°/second) than people who do not practice martial arts. Therefore, two questions arise: (1) is training duration related to greater knee and calf muscle strength in TKD athletes, and (2) would both slow and fast isokinetic testing speeds (i.e., knee and calf muscle contraction speeds) yield the same result? We hypothesize that the more time an individual spends in TKD training, the greater the muscle strength one could gain, regardless of the testing.

The goal of this study was to explore the relationship between duration of TKD practice, as defined by the number hours spent in training per week, and isokinetic lower limb muscle strength (at both slow and fast speeds) in young TKD practitioners. The findings of this study warrant further exploration into TKD training for the improvement of lower limb muscle strength and, therefore, athletic performance.

Methods

Twenty TKD practitioners (13 males and 7 females) aged 14—19 years old were recruited from two local TKD associations. Each had been practicing TKD for more than 2 years and trained between 1.3 and 15 hours per week (Table 1). Participants were excluded if they presented with cardiovascular, pulmonary, neurological or musculoskeletal disorders. This study was approved by the human subjects ethics review subcommittee of The Hong Kong Polytechnic University. Testing procedures were explained to the participants and written informed consent was obtained. All procedures were conducted in accordance with the Declaration of Helsinki.

Isokinetic muscle strength

A Cybex Norm isokinetic dynamometer (Computer Sports Medicine, Inc., Stoughton, MA, USA) was used to test knee flexor (hamstrings), knee extensor (quadriceps) and ankle plantar flexor (calf) muscle strength at both slow (60°/second) and fast (240°/second) speeds. Cybex Norm dynamometry has been shown to be high reliable for isokinetic testing of knee and ankle muscle strength in normal populations [10]. Testing was performed on all participants by the same investigator. Only the dominant leg, which was defined as the leg used to kick a ball, was tested in this study.

To test knee muscle strength, each participant was seated on the bench of the Cybex unit with the hip and knee at 85° and 90° of flexion, respectively. Seat belts were used to fix the trunk and the pelvis. The knee joint axis, which was demarcated by the lateral epicondyle of the knee, was aligned to the rotational axis of the dynamometer. The contralateral leg was also fixed by the limb stabilizer. Maximal concentric contractions of the hamstrings and quadriceps were measured in sequence at two different speeds (60°/second and 240°/second). After correcting for gravitational effects on knee torque, three familiarization trials were performed before actual testing. Three recorded trials were performed in order to measure the speed of knee extension and flexion; a 10-second rest interval was provided in between measurements. Each participant was instructed to provide maximal effort through the specified range of motion [11]. The average peak torques of the knee extensors and flexors across the three trials were normalized to the subject's body weight and used for further analysis.

To test the strength of the ankle plantar flexors, the participant was positioned in the prone position, with the thighs and legs were fixed to the Cybex bench by straps. The footplate was attached to the testing (dominant) foot. The axis of rotation of the ankle joint, which was defined by passing a line obliquely through the lateral malleolus and the distal end of the medial malleolus, was aligned to the rotational axis of the dynamometer. The maximal

Table 1 Demographic characteristics and TKD training durations of the participants ($n = 20$)

	Mean	Range
Age (y)	15.8 ± 1.2	14—19
Height (cm)	164.9 ± 5.0	155.0—173.0
Weight (kg)	54.0 ± 6.8	41.4—65.0
TKD experience (y)	6.2 ± 2.4	2.0—12.0
Duration of TKD training (h/wk)	4.3 ± 3.9	1.3—15.0

concentric contraction of the ankle plantar flexors was measured at two different speeds (60°/second and 240°/second). Three familiarization trials of the ankle dorsiflexion and plantar flexion were performed, which were followed by three trials to measure the maximal concentric contraction of the ankle plantar flexors/dorsiflexors. A 10-second rest was provided between trials [11]. The average peak torque of the ankle plantar flexors across the three trials was normalized to the subject's body weight and used for further analysis.

Data analysis

SPSS version 17.0 (SPSS Inc., Chicago, IL, USA) was used to analyze the data. Pearson's product-moment correlation coefficient (two-tailed) was used to analyze the relationship between TKD training duration and body weight-adjusted peak torque of the knee extensors, knee flexors and ankle plantar flexors at both contraction speeds (60°/second and 240°/second). Statistical significance was set at $p < 0.05$.

Results

The demographic characteristics of the participants are shown in Table 1. The duration of TKD training is significantly correlated with the peak torque of the knee extensors and flexors, but only at 240°/second ($r = 0.639$, $p = 0.002$ and $r = 0.472$, $p = 0.036$, respectively). There was no significant correlation between TKD training duration and peak torque of the knee flexors and extensors at the slower speed (60°/second), nor was there a significant correlation between TKD training duration and peak torque of the ankle plantar flexors at any speed (Table 2).

Discussion

Our results reveal moderate to strong positive correlations between the duration of TKD practice and the body weight-adjusted peak torque of both the quadriceps and hamstrings at high speeds (240°/second), but not at low speeds (60°/second). This finding suggests that TKD practitioners who spend more time in TKD training per week tend to have higher isokinetic quadriceps and hamstrings muscle strength than recreational practitioners who spend less time in TKD training. However, this significant correlation is limited to fast muscle contraction speeds only. This could be due to the fact that strength training of the muscles is velocity specific [12], as TKD kicks are very fast. Pieter and Pieter [3] studied the speed and force delivered by elite TKD athletes and found that these athletes could kick 5.2–16.26 m/second and generate 390.7–661.9 N depending on the kicking techniques [3,13]. Regarding the angular velocity of the knee extension during TKD kicks, O'Sullivan et al [14] reported that the knee's peak angular velocity was 1585.8°/second during a turning kick and 926.1°/second during a back kick [15], which are two common kicks used in TKD. Therefore, with repeated practice of these TKD kicks at fast speeds, athletes strengthen the muscles of their knees in order to perform these kicks at a high velocity.

In the present study, we also found that there was no correlation between duration of TKD practice and isokinetic knee muscle strength at slow contraction speeds (60°/second). Indeed, Bittencourt et al [16] showed that the muscle strength of TKD practitioners is not greater than control subjects at slow testing speeds (60°/second). TKD athletes even demonstrated lower body weight-adjusted peak torque of the knee flexors at 60°/second compared with nonathletes. This may be explained, again, by the velocity-specific strengthening of the leg muscles that occurs in TKD practitioners [12].

TKD training involves explosive kicks, jumps and shuffling footwork that require great strength and power from the calf muscles [5,6]. Surprisingly, there was no correlation between peak torque of the ankle plantar flexors (at 60°/second and 240°/second) and the duration of TKD practice. We postulate that the muscle strength of the ankle plantar flexors may have plateaued and was being maintained at a certain level after prolonged periods of TKD training by our participants (who had trained for a minimum 2 of years; average: 6.2 years) [17]. Further prospective studies are needed to confirm the effect of TKD training on lower limb muscle strength in adolescents.

The present study shows that there is a positive correlation between the duration of TKD training and isokinetic knee muscle strength at high speeds (240°/second). A more comprehensive picture of the velocity-specific "training dosage" of TKD has now been established. Further studies are needed to determine the optimal training parameters required to improve muscle strength and sports performance in adolescent TKD athletes.

There are some limitations of this study that need to be considered when interpreting the results. First, this is an exploratory study that shows that the duration of TKD training may be associated with knee muscle strength. These findings are very preliminary. Further longitudinal studies are needed to confirm the effect of TKD training on the lower limb muscle strength, as well as the optimal amount of training required to improve athletic performance. Second, our measure of "training duration" is self-reported. Additional studies that measure TKD training duration without relying solely on self-reported data may improve the validity of the findings. Finally, we recruited a wide range of study participants in terms of age (14–19 years old). Muscle strength may be influenced by growth factors [18], in addition to the effects of TKD training, in these developing individuals.

Table 2 Correlation between duration of TKD training and isokinetic muscle strength of the dominant leg ($n = 20$)

Body weight-adjusted peak torque (N/kg)	TKD training duration (h/wk)
	r
Knee extensor (60°/s)	0.426
Knee extensor (240°/s)	0.639[a]
Knee flexor (60°/s)	0.337
Knee flexor (240°/s)	0.472[a]
Ankle plantar flexors (60°/s)	−0.129
Ankle plantar flexors (240°/s)	−0.026

[a] $p < 0.05$.

In summary, this study demonstrates that there is a positive correlation between the duration of TKD practice (number of training hours per week) and isokinetic muscle strength of both the quadriceps and hamstrings at fast speeds (240°/second), but not at slow speeds (60°/second). Our findings support the notion that the more time one spends in TKD training the greater the muscle strength one could gain and that improvements in knee muscle strength is velocity specific. Further study is needed to confirm the optimal amount of training required and parameters necessary to develop knee muscle strength in TKD athletes.

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