J. Phys. Ther. Sci. 28: 250–256, 2016

The Journal of Physical Therapy Science

Original Article

Comparative study on isokinetic capacity of knee and ankle joints by functional injury

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Abstract. [Purpose] To collect basic data for exercise programs designed to enhance functional knee and ankle joint stability based on isokinetic measurement and muscle strength evaluations in normal and impaired functional states. [Subjects and Methods] Twenty-four subjects were randomly assigned to the athlete group and the control group (n = 12 each). Data were collected of isokinetic knee extensor and flexor strength at 60°/sec, 180°/sec, and 240°/sec and ankle plantar and dorsiflexor strength at 30°/sec and 120°/sec. [Results] Significant intergroup differences were observed in peak torque of the right extensors at 60°/sec, 180°/sec, and 240°/sec and the right flexors at 240°/sec. Significant differences were observed in peak torque/body weight in the right extensors at 60°/sec, 180°/sec, and 240°/sec and in the right flexors at 180°/sec and 240°/sec. Significant peak torque differences were noted in the left ankle joint dorsiflexor at 30°/sec and 120°/sec, right plantar flexor at 120°/sec, left plantar flexor at 30°/sec, left dorsiflexor at 30°/sec and 120°/sec, and right dorsiflexor at 120°/sec. [Conclusion] Isokinetic evaluation stimulates muscle contraction at motion-dependent speeds and may contribute to the development of intervention programs to improve knee and ankle joint function and correct lower-extremity instability.
Key words: Isokinetic, Knee and ankle joints, Functional injury

(This article was submitted Sep. 16, 2015, and was accepted Oct. 16, 2015)

INTRODUCTION

Dynamic knee stability is defined as the state responding to the proprioceptive feedback alerted by recurring postural instability caused by limited range of motion (ROM) and restricted movement[1)]. Pain and functional instability are the most common pathological conditions of the knee joint. Mechanical knee joint injuries are primarily associated with meniscal lesions, and knee pain and mechanical disorders are easily overlooked[2)]. Recurring disorders arising from diminished ROM and muscle strength are reportedly caused by altered muscular reflexes of the tissues surrounding the knee joint due to early trauma or chronic damage and insufficient proprioception[3)]. Muscular stability, especially that of the quadriceps, is essential for functional recovery of the knee joint[4, 5)], and knee bone malalignment, overstress, and muscular weakness around the hip joints are the most common causes of functional abnormalities[6–8)]. Knee instability can lead to lower-limb collapse due to the pain control mechanism of the quadriceps femoris under patellofemoral joint loading in an upright standing position. Pain in the knee joint can be caused by accumulated injuries, traumatic patellar dislocation, knee bone malalignment, increased compressive pressure due to obesity or load-lifting, and primary knee osteoarthritis, which can lead to secondary knee osteoarthritis and is likely to be accelerated by obesity[9)].

The ankle joint has various functions, such as weight-bearing, static and dynamic motion and control, walking, running, jumping, landing from a jump, and shock absorption. It also plays an important role in ensuring a stable base of support and flexibility through biomechanical compensation in motions coordinated by the knee and hip joints[10)]. Functional ankle

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instability is a condition of ankle joint weakness ("give way" feeling) without a structural problem due to recurrent ankle sprains or high-intensity track and field exercises. Not only does it cause recalcitrant chronic problems for athletes, it can also manifest as lesions with many different forms[11, 12]. Hertel noted that chronic ankle instability is associated with several functional impairments, such as decreased muscle strength, affected proprioception, inadequate neuromuscular control, and postural control loss[13]. The results of recurrent and chronic ankle sprains can be classified into diminished ROM, anthropometric changes, ligament laxity, and regenerative changes. Functional ankle instability can be classified as changes that affect stability due to the lack of dynamic postural control during functional motions including walking[14, 15]. Appropriate muscle contractility is an efficient indicator of muscular function for athletes and non-athletes alike[16, 17] and can be safely and simply applied to muscle imbalance correction and muscle damage recovery interventions.

Based on these theoretical factors, this study aimed to establish basic data that may be efficiently applied to the development of exercise programs designed to improve the functional stability of the knee and ankle joints. To this end, we performed isokinetic measurements and evaluated knee and ankle muscle strength in functionally intact and affected states to identify problems during functional activities in the lower limb joints and muscles.

SUBJECTS AND METHODS

For the experiments in this study, we enrolled 12 male high school athletes (five basketball and seven volleyball players) who had been treated in the hospital for functional instability of the knee and ankle joints in the preceding 12 months as well as 12 age- and gender-matched healthy controls. All 24 subjects were right-handed. The subjects provided written informed consent prior to participating. The study was approved by the HUFS University and the institution in which it was performed and complied with the ethical standards of the Declaration of Helsinki. The subjects' general characteristics are shown in Table 1.

The isokinetic strength variables of the knee and ankle joints were measured using the Humac Norm Testing & Rehabilitation System (CSMi, USA). The experimental procedure and measurement setup for the knee joint were as follows. The subject was seated on the measurement chair, and the knee positions were adjusted using a table-tube cross-clamp and a pedestal column clamp to align the axis of rotation of the knee joints with that of the isokinetic dynamometer. The thighs and trunk were firmly fastened using straps and belts to prevent the parts other than the target joints from exerting external force on the muscular motions of the thighs during the knee flexion and extension exercises. During the knee flexion and extension exercises, muscle activation of the target region was facilitated by adjusting the lengths for the lower legs and the adjustment axis using a long input adapter and an adjusting arm followed by fixing of the ankle region with Velcro straps. The subject was requested to execute knee joint flexion and extension from 135° to 0° and from 0° to 135°, respectively, whereby the ROM was controlled to prevent hyperextension or hyperflexion. Prior to the measurement sessions, the subjects performed pre-speed warm-ups in which they performed three submaximal and one maximal flexion and extension exercise at loading speeds of 60°/sec (five repetitions), 180°/sec (10 repetitions), and 240°/sec (20 repetitions) with a 2-min rest after each measurement.

Ankle joint plantar- and dorsiflexion strengths were measured at 30°/sec and 120°/sec as described above. Measurements were performed in each group after pre-speed warm-ups in which the subjects underwent three submaximal and one maximal ankle plantar- and dorsiflexion exercises at speeds of 30°/sec (five repetitions) and 120°/sec (15 repetitions) with a 2-min rest after each measurement. The researcher verbally encouraged the subjects to perform the exercises to their maximum capacity for all measurements.

The measurement results were processed by SPSS for Windows version 20.0 software (SPSS Inc., USA). Mean and standard deviation were calculated for each measurement variable, and intergroup differences were analyzed using independent t-tests with the statistical significance level set to $p < 0.05$.

RESULTS

The peak torque measurements for the knee joint revealed statistically significant intergroup differences between the functionally affected athlete group and the healthy control group for right extensor strength at 60°/sec, 180°/sec, and 240°/sec as well as right flexor strength at 240°/sec, while the remaining variables showed no statistically significant intergroup differences (Table 2). For peak torque/body weight (PTBW), intergroup differences were observed for right extensor strength at 60°/sec, 180°/sec, and 240°/sec and for right flexor strength at 180°/sec and 240°/sec (Table 3). Comparison of left/right peak torque ratios did not yield statistically significant differences for any of the variables at exercise speeds of 60°/sec, 180°/sec, and 240°/sec (Table 4).

The peak torque measurements for the ankle joint revealed statistically significant intergroup differences between the affected and healthy groups for left dorsiflexor strength at 30°/sec and 120°/sec and for right plantar flexor strength at 120°/sec (Table 5). For PTBW, intergroup differences were observed for left plantar flexor strength at 30°/sec, left dorsiflexor strength at 30°/sec and 120°/sec, and right dorsiflexor strength at 120°/sec (Table 6). Comparison of left/right peak torque ratios did not yield any statistically significant differences at 30°/sec and 120°/sec (Table 7).

Table 1. Subjects' general characteristics

Group	N	Age (yrs)	Height (cm)	Weight (kg)
Athlete	12	16.8±1.9	181.1±5.5	71.1±8.6
Control	12	20.3±1.5	177.3±6.8	72.2±7.5
Total	24	18.6±2.4	179.2±6.3	71.6±7.9

Values are mean ± SD

Table 2. Comparison of peak torque of the knee joint

Variable		Athlete group	Control group
Extensors (Nm) at 60°	Right	232.1±72.1	179.8±28.6*
	Left	156.3±69.1	178.1±34.2
Flexors (Nm) at 60°	Right	135.5±32.2	119.7±26.3
	Left	96.4±38.2	108.4±23.9
Extensors (Nm) at 180°	Right	134.6±42.8	100.5±19.1*
	Left	90.0±41.4	96.3±18.7
Flexors (Nm) at 180°	Right	89.6±24.8	73.0±15.8
	Left	72.6±32.4	67.6±14.5
Extensors (Nm) at 240°	Right	112.0±27.8	79.4±14.6**
	Left	80.2±27.0	80.6±13.5
Flexors (Nm) at 240°	Right	85.2±25.0	67.1±9.3*
	Left	67.5±30.1	59.8±12.9

Values are mean ± SD; *$p < 0.05$, **$p < 0.01$

Table 3. Comparison of peak torque/body weight of the knee joint

Variable		Athlete group	Control group
Extensors (%) at 60°	Right	325.7±81.0	251.5±41.3*
	Left	217.8±74.0	222.8±70.4
Flexors (%) at 60°	Right	193.3±32.6	166.4±35.6
	Left	133.8±41.9	137.6±47.6
Extensors (%) at 180°	Right	188.8±50.3	140.5±28.7**
	Left	124.7±42.8	123.2±46.7
Flexors (%) at 180°	Right	125.3±26.4	98.5±25.0*
	Left	99.9±35.9	86.3±32.0
Extensors (%) at 240°	Right	157.5±34.3	111.9±24.5**
	Left	112.3±28.7	103.2±37.1
Flexors (%) at 240°	Right	118.8±27.9	93.6±13.8*
	Left	92.8±33.1	76.9±27.8

Values are mean ± SD; *$p < 0.05$, **$p < 0.01$

Table 4. Comparison of bilateral balance ratio of the knee joint

Variable		Athlete group	Control group
Ratio (%) at 60°	Right	61.6±14.4	67.0±16.0
	Left	63.5±16.1	61.2±8.8
Ratio (%) at 180°	Right	68.8±13.6	72.3±14.8
	Left	81.6±22.5	71.0±12.8
Ratio (%) at 240°	Right	77.3±17.9	86.4±17.4
	Left	84.5±26.7	75.1±17.0

Values are mean ± SD

Table 5. Comparison of peak torque of the ankle joint

Variable		Athlete group	Control group
Plantarflexors (Nm) at 30°	Right	73.5±26.4	66.9±21.3
	Left	51.6±24.2	68.0±21.1
Dorsiflexors (Nm) at 30°	Right	30.3±5.0	29.6±3.6
	Left	19.4±4.4	29.7±5.9***
Plantarflexors (Nm) at 120°	Right	39.9±14.7	38.8±18.5
	Left	29.7±15.4	35.2±12.2
Dorsiflexors (Nm) at 120°	Right	16.0±3.0	13.3±2.2*
	Left	9.8±2.3	13.8±4.7*

Values are mean ± SD; *p < 0.05, ***p < 0.00

Table 6. Comparison of peak torque/body weight of the ankle joint

Variable			Athlete group	Control group
30	Plantarflexors (%)	Right	103.4±32.5	92.3±25.0
		Left	71.1±26.1	94.7±27.4*
	Dorsiflexors (%)	Right	42.8±6.2	41.5±4.9
		Left	27.5±5.8	42.5±11.2***
120	Plantarflexors (%)	Right	56.8±19.4	53.7±24.5
		Left	41.5±18.5	50.4±20.5
	Dorsiflexors (%)	Right	23.0±5.0	18.5±3.6*
		Left	14.3±2.9	19.8±8.0*

Values are mean ± SD; *p < 0.05, ***p < 0.00

Table 7. Comparison of bilateral balance ratio of the ankle joint

Variable		Athlete group	Control group
Ratio (%) at 30°	Right	46.0±17.4	48.0±15.3
	Left	43.2±14.2	51.7±30.8
Ratio (%) at 120°	Right	43.3±14.5	44.5±26.8
	Left	42.9±24.4	46.4±26.2

Values are mean ± SD

DISCUSSION

Peak torque of the lower limbs and bilateral balance ratios are most commonly used to assess the isokinetic strength of the lower limb muscles, detect injuries, and predict risk[18]. Jumping is one of the most common motions, and the landing or directional change after jumping motion should be executed fluidly and stably under conditions of adequate muscle activation with components of complex muscle extension and flexion movements[19]. Jumping height depends on flexion and extension of the knee and ankle joints, and repeated excessive use of the lower limb joints is considered responsible for 50–80% of injuries[20].

The knee joint can extend and flex to execute stable motions. Extension is primarily performed by the quadriceps femoris muscle, which is also responsible for the weight-bearing and postural balance used for body axis alignment, stability, and walking[21–23]. Damage to the knee joint in particular is likely to increase postural imbalance and falling risk by inducing abnormal responses in the muscles surrounding the knee including loss of muscle strength and subsequent fatigue. Kim performed a large-scale 2 year prospective cohort study of 1,060 Korean male professional volleyball players that focused on injury sites and types and found that the lower extremities sustained 63.4% of all injuries, with the knee showing the highest risk of injury, followed by the ankle, lower leg, thigh, and foot. In a 4 year study on injuries among female college volleyball players[24], Agel et al. also reported lower extremity injury rates of 58.7% during the season and 55.9% during training[25]. Given that muscle performance in jumping significantly relies upon lower-extremity extension strength in the knee and then the ankle joint, identifying muscle performance abnormalities may be useful for determining the causes of imbalanceinduced functional instability and creating corrective strategies[26]. In a study in soccer players, Choi et al. reported significant differences between knee extensor and flexor isokinetic strength (247.9 ± 34.4 Nm vs. 165.1 ± 29.4 Nm) and ascribed higher flexor strength in high-performing players to the fact that knee flexors play an important role in enhancing sprinting speed and stability in the execution of various motions involving the knee joint[27]. Chun et al. compared the isokinetic muscle strength characteristics of elite soccer players and non-athletes and reported that, the control group (220.7 ± 16.2 Nm) showed lower right extensor strength at 60°/sec compared to college (260.4 ± 16.1 Nm) and professional soccer players (256.9 ± 15.4 Nm), respectively[28]. In addition, similar results were observed at 180°/sec suggesting that college and professional soccer players showed higher right extensor strength compared to the control group. These results were similar to the results of the present study that yielded statistically significant differences between the athlete and control groups.

Individuals with chronic ankle instability have diminished ROM due to lower-extremity muscle atrophy and postural imbalance; thus, they encounter problems with balance and walking, motions that comprise the basis for all physical activities. Furthermore, they are at high risk of recurrent injuries and functional movement limitations such as postural sway. A recent meta-analysis of ankle sprains and chronic ankle instability highlighted the need for an in-depth investigation of functional impairment causes and noted that diminished dynamic and static postural control ability can trigger earlier recurrence of ankle sprains[11, 29–31]. Ji et al. reported that the isokinetic peak torque of the ankle joint in concentric contraction showed significant differences between ankle instability and stability groups in a study of the impact of functional ankle instability on the strength of the muscle surrounding the ankle, balance ability, and functional performance; specifically, differences were observed in plantar flexor strength at 30°/sec, 60°/sec, and 120°/sec and in plantar flexor and dorsiflexor strength at 30°/sec with respect to PTBW[32]. These results verified the high risk of recurrent functional instability due to ankle joint weakening. Moreover, the results are in line with those of the present study in which significant intergroup differences were demonstrated in the peak torque of left ankle dorsiflexor strength at 30°/sec and in peak torque of bilateral dorsiflexor strength and PTBW at a loading speed of 120°/sec.

Gribble and Robinson compared the muscle strength of the ankle, knee, and hip joints with regard to the biomechanical and dynamic chain relationships to chronic ankle instability[33] and reported that the affected side showed significantly lower values than the healthy side in the isokinetic evaluation of plantar flexor (ankle) and flexor and extensor (knee) strength. In the present study, significant differences were demonstrated in peak torque, PTBW, and peak torque ratios in the plantar- and dorsiflexors and in the peak torque, PTBW, and peak torque ratios comparing plantar and dorsiflexors; significant differences between the healthy and affected sides were observed ($p < 0.001$). These results are consistent with the values for isokinetic variables in a study by Kim and Jeon of 175 subjects with symptoms of chronic and functional ankle instability[34]. These results also allow the conclusion that enhancing plantar and dorsiflexor strength will stimulate postural balance recovery[35] and be conducive to securing ankle joint stability[36, 37].

In conclusion, isokinetic evaluation stimulates muscle contraction at loading speeds based on ROM and carries a very low risk of exercise-induced injury. These valuable basic data will assist in the development of efficient and complex intervention programs to improve knee and ankle joint function according to injury degree and will ensure safety by correcting lower-extremity instability and muscle strength losses due to various causes.

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