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https://doi.org/10.20540/JIAPTR.2018.9.1.1426

# Assessment and Comparison of Isokinetic Strength of Hip, Knee and Ankle Joints in Young Adults

This study was conducted to observe the isokinetic strength (IS) of the hip, ankle, and knee joints in young age groups. Thirty eight men and thirty one women with mean age of 30.4 ± 3.5 and 32.8 ± 4.4 years, respectively, were enrolled in this study. Measurements of hip flexion, extension, abduction, and adduction at 30° / sec, Knee flexion and extension at 60° / sec, ankle inversion, eversion, plantarflexion, and dorsiflexion 30° / sec were conducted. Absolute IS (Nm), relative IS (Nm/kg), strength ratios, correlations between movements were observed. Significant differences in absolute and relative strength were observed between groups in all movement except in the relative ankle strength. Relative isokinetic strength ratios of hip flexion/extension were .45 and .55, knee flexion/extension were .84 and .89, ankle dorsi/plantarflexion were .30 and .29, and ankle eversion/inversion were .86 and .84 for men and women, respectively. In the hip extension, men had about three times the body weight ,and women had about 2.5 times the strength. The abduction muscle had about 1.5 times the body weight of both men and women. Height and body weight showed the significantly strong correlating relationship with hip (r, .76–.86) and knee (r, .67–.84) strength. However, ankle strength showed the comparatively correlating relationship, especially in women (r, .03 – .36). Similar age and physique characteristics of female and male groups could provide useful isokinetic strength reference values for developing the exercise program for healthy and rehabilitation groups.

Key words: *Isokinetic, Strength, Hip, Ankle, Knee*

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Received : 13 January 2018
Revised : 18 February 2018
Accepted : 22 February 2018

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## INTRODUCTION

As the number of joint injury increases every year with notably growing sports population, various efforts have been made by the experts in the field of sports medicine to analyze the causes of various forms of injury and apply preventive programs to maintain a healthy body [1]. Typically, prioritized preventative modality in such damage-related model has been strengthening or balanced muscle strength. Muscle strength has been reported to be highest at the age of 30 years and tend to gradually decrease thereafter [2]. Muscle strength is a good indicator for assessing injury recovery status and is a useful marker for evaluating status for returning to work and functional performance after injury. It is also useful in developing program for injury prevention [3]. Although the 1 repetition maximum (RM) measurement method is most widely used representative method of measuring muscle strength, the most accurate method is the one that using isokinetic equipment, considering reliability, validity, safety and objectivity of the test [4]. There have been several studies on providing standard values of healthy people using isokinetic equipment, however, most of them were conducted in the 1980s when machines were developed and popularized. Such earlier reports have several limitations requiring for updated guideline on isokinetic strength.

First, the subjects for the earlier reports were mostly athletes and patients. Costly isokinetic machines and manpower limited assessment targets to those critically in need of the care such as patients, athletes and research subjects [5]. In reality, despite the fact that the number of general population is much higher than that of the athletes or patients, most of the studies have conducted to certain group of people, limiting the ability to measure the strength of general public in Korea. Second, the differences in machine design, assessment protocol, and design changes lead differences in values and need for assessment despite possibility of repeated measures. Thirdly, although a lot of studies have been done on frequently injured areas such as knee, a limited number of studies on ankle and knee strength has been conducted both on the domestic and international levels. A limited number of studies have been reported on knee despite its strong relationship with chronically unstable eversion, plantar flexion in Achilles tendon injury, recovery after hip arthroplasty, and gate analysis [6–8]. Despite the need for reference values of the isokinetic strength of different joints, such information is hardly reported. Reference values are needed for relative comparison between similar peer groups either by gender, age, or physiological status. Reference values are usually utilized in clinical fields to compare the physical status and applicability of certain intervention during treatment. Therefore, the purpose of this study is to measure hip and ankle isokinetic strength during various movements and to providing reference values for young male and female adults for comparison between the measurements.

## SUBJECTS AND METHODS

### Subjects

This study was conducted with 38 men and 31 women aged between 30.4±3.5 and 32.8±4.4 years, respectively. Participants were recruited from sports medicine center through recruitment posters around the clinic. Bulletin boards were used to guide the purpose and method of the study and to participate voluntarily. Participant voluntarily requested for information and participation. Participants who have surgery or recent history of joint damage were excluded. Participants with professional athletic experience were also excluded. Upon selection, the participants were thoroughly explained of the procedure and purpose of the study. Those who agreed to participate in the study expressed their consent via writing. Before conducting the isokinetic test, the participants were assessed for the height and weight.

### Measurement Methods

#### Isokinetic muscular strength test

Before the test was performed, the test method was described in detail and adequate warm up was carried out with a bicycle, a treadmill, and light weight training. Isokinetic test equipment Cybex 770 and Humac norm software (HUMAC NORM, USA) were used to assess 3 joints of hip, knee, and ankle. Inversion, and eversion, plantarflexion and dorsiflexion strength were assessed on the ankle, extension and flexion strength were assessed on the knee, and extension, flexion, abduction, and adduction strength were assessed on the hip. Because assessing muscular strength was the main goal in this study, one type of low angular speed was used for assessment. Angular speeds of 60° / sec was used for the knee, angular speed of 30° / sec was used for the ankle, and angular speed of 30° / sec was used for the hip with the concentric contraction method. According to the general assessment guidelines, gravity corrections were performed for all tests by measuring the weight of the limb segments. The participants were asked to perform three non-recorded practices on the machine for adequate adaptation. After 30–60 seconds of rest after practice, test was performed four times to exert maximum muscle strength [9, 10]. Isokinetic strength assessment of the hip, knee, and ankle joints were conducted for all participants in such manner.

Sharp and loud commands were provided to induce distinctive and continuous expression of maximal force by the participants. The tests were re-conducted if abnormal parabolic graph pattern was shown, two or graphs were distinctively different from others, or the participants indicated failure to express full force during the test. Results were recorded in Nm, which is the absolute value, and Nm / kg, the muscle strength value per body weight.

Hip extension and flexion were performed in the lying position, and hip abduction and adduction were performed in the lateral position. The test pad was positioned at the distal end of the femur just above the patella. Flexion started from 100 to 0 degree extension point and adduction started from neutral position to 45 degree abduction point. In order to prevent disturbance of the posture when the force is exerted, the upper body and the opposite legs were fixed, and caution was taken to prevent rotation of the thighs and trunk.

Ankle inversion and abduction were performed with the hip and knee bent at 90°, and foot placed on a pedestal. Based on a neutral position, the second toe, knee, and shoulder were positioned side by side. The test was initiated from 30 degree eversion to 40 degree inversion. The plantarflexion and dorsiflexion were initiated in the lying position with the knees and hip straightened. The axis was set at the center of the lateral radioulnar bone. The test was started at 10 degree dorsiflexion to 35 degree plantarflexion. The knee test was performed at a sitting position with the lateral epicondyle as the axis of the joint. The force pad was fixed just above the ankle or the tip of tibia. The examination angle was started at a flexion of 90 degree, to 0 degrees of complete spreading, and the woman was careful not to hyper-extension due to excessive flexible joints. Upper body, knee, and opposite side were fixed for accuracy of examination.

### Data analysis

Data were analyzed using SPSS 21.0. Male and female participants were divided and analyzed. Muscle strength and body weight were calculated with ratios. Hip extension and flexion, hip adduction and abduction, knee extension and flexion, ankle eversion and inversion, and ankle dorsiflexion and plantar flexion values were calculated by applying the method used in previous studies. Differences according to gender were tested by independent t-test. Pearson's correlation analysis was conducted to determine the effect of segment length on the age, weight, and torque values that generally affect muscular strength. Correlation coefficients between .4 and .6 were considered 'moderate', .6 and .8 were considered 'substantial', coefficients greater than .8 were regarded as 'excellent' or nearly perfect 11). The significance level of $a$ = .05 was used for all analysis, and in the correlation analysis, the significance level of $a$ = .01 was used together with $a$ = .05.

## RESULTS

Table 1 shows the general characteristics of the participants. The mean ages and BMI (body mass index) were significantly higher in women than in men (p〈 .05). Representative muscle strength of each joint region was calculated (Table 2). Hip abduction strength were significantly different between men and women (p 〈 .01). The highest muscle strength per body weight was shown for the hip extension (p〈 .05). Hip abduction strength were significantly different between men and women (p 〈 .01). Ankle eversion strength normalized with weight were were different between men and women without significant difference (p = .10). The plantarflexion strength were significantly different between men and women (p 〈 .01). As for the relative plantarflexion strength normalized by body weight, there was no significant difference in relative muscle strength (p = .12).

**Table 1.** Subject characteristics

| Variables | Men (n=38) | Women (n=31) | p |
|---|---|---|---|
| Age (years) | 30.4±3.5 | 32.8±4.4 | .01* |
| Height (cm) | 175.1±4.5 | 163.4±4.0 | .00** |
| Weight (kg) | 75.5±10.2 | 56.2±6.6 | .00** |
| BMI (kg/m2) | 24.6±3.3 | 21.0±2.2 | .00** |

Mean±SD, *p〈0.05, **p〈0.01

**Table 2.** . Absolute (Nm) and relative (Nm/kg) strength of the hip, knee, and ankle joint movements

| | Men(Nm) | Women(Nm) | p | Men(Nm/kg) | Women(Nm/kg) | p |
|---|---|---|---|---|---|---|
| Hip, 30°/sec | | | | | | |
| Extension | 221.8±29.3 | 144.1±19.6 | .00* | 2.98±.49 | 2.58±.37 | .00* |
| Flexion | 155.4±26.6 | 94.7±16.2 | .00* | 2.07±.34 | 1.69±.22 | .00* |
| Abduction | 125.5±20.9 | 85.6±13.0 | .00* | 1.66±.17 | 1.53±.25 | .01* |
| Adduction | 131.2±24.7 | 85.4±12.4 | .00* | 1.74±.26 | 1.54±.26 | .00* |
| Knee, 60°/sec | | | | | | |
| Extension | 187.8±27.6 | 103.7±9.4 | .00* | 2.50±.28 | 1.86±.18 | .00* |
| Flexion | 103.7±17.5 | 56.0±9.6 | .00* | 1.39±.25 | 1.00±.12 | .00* |
| Ankle, 30°/sec | | | | | | |
| Inversion | 40.7±9.2 | 27.6±6.3 | .00* | .54±.12 | .49±.10 | .06 |
| Eversion | 34.2±8.7 | 23.1±6.2 | .00* | .46±.12 | .41±.11 | .10 |
| Plantarflexion | 117.5±17.8 | 82.5±21.6 | .00* | 1.58±.27 | 1.46±.32 | .12 |
| Dorsiflexion | 35.3±6.1 | 23.5±5.8 | .00* | .47±.08 | .42±.08 | .01* |

Mean±SD, *p<.05, **p<.01

There was no significant difference in the proportion of muscle strength between men and women (table 3). The hip extension to flexion strength ratios were not significantly different between men and women (p = .07) The adduction to abduction strength ratios were not significantly different between men and women (p = .09) respectively. The adduction to abduction ratios were similar (p = .09). The knee flexion to extension ratios were not significantly different between men and women (p = .45). The extension ratio was about twice as high as that of flexion, and ankle eversion to inversion ratios were also not significantly different between men and women (p = .48).

**Table 3.** .Isokinetic strength ratios of the hip, knee, and ankle joint movements

| motions | Men | Women | p |
|---|---|---|---|
| Hip, 30°/sec | | | |
| Extension to Flexion | 1.45±.21 | 1.55±.23 | .07 |
| Adduction to Abduction | 1.05±.12 | 1.00±.09 | .09 |
| Knee, 60°/sec | | | |
| Flexion to Extension | 1.84±.28 | 1.89±.27 | .45 |
| Ankle, 30°/sec | | | |
| Eversion to Inversion | .86±.21 | .84±.15 | .64 |
| Dorsiflexion to Plantar flexion | .30±.06 | .29±.06 | .48 |

Mean±SD, *p<.05, **p<.01

To determine the effect of the age, height, and body weight factors on the torque value, Pearson's correlation analysis was conducted for each joint movement (table 4). Age did not affect muscular strength except for the hip extension, ankle eversion, and plantarflexion in men. As for women, age significantly affected hip extension strength. There was a significant correlation between height and body weight in all men and significant correlation between hip and knee extension strength in women.

**Table 4.** . Pearson's correlation coefficients of isokinetic strength of the hip, knee, and ankle joint movements

| | Men | | | Women | | |
|---|---|---|---|---|---|---|
| | Age (r) | Height (r) | Weight (r) | Age (r) | Height (r) | Weight (r) |
| Hip, 30˚/sec | | | | | | |
| Extension | 0.38** | .84** | .67** | −.33* | .45** | .06 |
| Flexion | −.23 | .86** | .76** | −.10 | .66** | .34* |
| Abduction | −.20 | .80** | .84** | −.05 | .58** | .78** |
| Adduction | −.23 | .72** | .79** | −.07 | .38* | .64** |
| Knee, 60˚/sec | | | | | | |
| Extension | −.21 | .83** | .85** | .12 | .39* | .63** |
| Flexion | −0.19 | .76** | .75** | .14 | .13 | .22 |
| Ankle, 30˚/sec | | | | | | |
| Inversion | −.19 | .59** | .66** | −.04 | −.03 | .36* |
| Eversion | −.24* | .59** | .56** | −.22 | .13 | .20 |
| Plantarflexion | −.33** | .68** | .66** | −.17 | .21 | .21 |
| Dorsiflexion | −.17 | .69** | .68** | .05 | .25 | .22 |

r = correlation coefficient, *p〈.05, **p〈.01

The correlation between joint movements was analyzed (table 5). Significant correlations were shown between movements of all joints in men (p 〈.01). However, unlike men, women did not show correlations in all areas. However, since quadriceps was the major strengthening muscle during hip flexion and knee extension, significant correlation value of r = .427 was observed. Although muscle activated during hip extension and flexion was posterior to femur, significance was not observed.

**Table 5.** . Correlating relationship between isokinetic strength of hip, knee, and ankle movement types and groups

| | Women | Hip (r) | | | | Knee (r) | | | | Ankle (r) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Men | Types | Ext | Flx. | Abd. | Add. | Ext. | Flx. | Inv. | Ev. | Pf. | Df. |
| Hip | Ext. | | .57** | .50** | .52** | .26 | .26 | −.06 | .12 | .44** | .39* |
| | Flx. | .85** | | .65** | .49** | .43** | .24 | .10 | −.15 | .40* | .23 |
| | Abd. | .82** | .84** | | .80** | .68** | .28 | .30 | .26 | .31 | .38* |
| | Add. | .81** | .78** | .91** | | .61** | .40* | .33* | .27 | .23 | .22 |
| Knee | Ext. | .82** | .83** | .85** | .84** | | .53** | .28 | .33* | .24 | .23 |
| | Flx. | .79** | .79** | .74** | .77** | .88** | | .18 | .12 | .24 | .06 |
| Ankle | Inv. | .61** | .62** | .70** | .68** | .68** | .63** | | .47** | .22 | −.12 |
| | Ev. | .59** | .48** | .64** | .60** | .65** | .57** | .71** | | −.06 | .10 |
| | Pf. | .77** | .73** | .69** | .63** | .67** | .69** | .67** | .50** | | .39* |
| | Df. | .76** | .71** | .71** | .67** | .72** | .68** | .52** | .50** | .71** | |

r = correlation coefficient, *p〈.05, **p〈.01. gray boxes: men, white boxes: women, r: Pearson's correlation coefficient, Gray block: men's r, white block: women's r. Ext: extension, Flx: flexion, Abd: abduction, Add: adduction, Inv: inversion, Ev: eversion, PF: plantarflexion, Df: dorsiflexion

## DISCUSSION

Isokinetic strength is one of the types of muscular contraction for creating muscle strength along with isometric and isotropic strength. Although all types of muscular strength should be assessed to meet specific purpose, isokinetic strength is least accessible due to the cost of equipment and professional status of the assessor. However, assessment of isokinetic strength measurement is safe, reliable, and objective. Furthermore, it has advantage of delivering various loads using angular velocity [4]. Primary purpose of this study was to evaluate the hip extension and flexion, hip abduction and adduction, knee extension and flexion, ankle plantarflexion and dorsiflexion, ankle eversion and inversion strength in absolute values and relative values normalized in body weight to provide reference values for healthy and clinically limiting subjects. This study focused on obtaining isokinetic muscular strength values of the knee, ankle, and hip.

Absolute isokinetic strength (Nm) was higher in men than in women, however, relative muscular strength per body weight (Nm/kg) did not show a significant difference between the groups. Dorsiflexion showed a significant difference in relative value in the most distal ankle, but inversion, eversion, and plantarflexion were not significant. Hip extension showed the highest muscular strength per body weight in both men and women. Men's extension strength was about 2.98 times the body weight and women' extension strength was about 2.58 times the female body weight. Flexion, antagonist to extension, showed 65% muscle strength compare to extension in both men and women. Studies on healthy people were mainly conducted in the early days [12]. Previous study reported of men's extension of 177 Nm and flexion of 152 Nm, and women's extension of 110 Nm and flexion of 91 Nm at the same angular velocity as in the present study. In a similar study by Harbo et al. (2012), the extension and flexion were reported to be 149 Nm and 105 Nm for women and 202 Nm and 151 Nm for men, respectively [13]. There are only a few domestic researches related to Hip. Only 12 cases were found with the key words 'hip isokinetic' from the Korean Academic Information (KISS) database. Among the 12 cases, most of the researches were conducted on patients, athletes, and athletic students majoring in sports. In a few studies, normal college-aged subjects were assessed for the isokinetic strength. In one of the studies, 18 years old men's hip extension and flexion were 248 Nm and 164 Nm, respectively, which were about 10% greater than the findings of this study [14]. In a study of male students majoring in physical education, extension was 3.9 to 5.3 times that of body weight and flexion was 3.0 to 3.6 times that of body weight. In a study of Taekwondo players with chronic ankle pain, abduction was 125 Nm, adduction 83 Nm, which was largely different from that of findings of this study [15,16].

A study conducted by Harbo et al. (2012) was one of the largest studies on isokinetic strength with 178 patients. The results were similar to those of the present study with ankle plantarflexion and dorsiflexion strength of 111 Nm and 33 Nm in men, and 76Nm and 21Nm in women, respectively [13]. In other study, plantarflexion and dorsiflexion strength of 126 Nm and 33 Nm were reported in similarly aged men, and 84 Nm and 26 Nm in similarly aged women, respectively [4]. Furthermore, Inversion and eversion strength of 32Nm and 28Nm for men and 24Nm and 20Nm for women were shown, respectively. Although men showed slightly higher strength, women showed similar results in this study. Very few studies could be found on studies on ankle in Korea. In a study, plantarflexion and dorsiflexion strength of the female college students were 63 Nm and 19 Nm, respectively, and the plantarflexion was slightly higher [17]. In a study of female dancers in other studies, inversion and eversion strength were 33 Nm and 28 Nm, respectively, which was slightly higher than the results of this study. Dorsiflexion strength results were similar and plantarflexion strength results were slightly higher to that of the results of this study. In a study conducted on female dancers, inversion and eversion strength were 33 Nm and 28 Nm, respectively, which were slightly higher than this study which was done on normal young subjects [17]. Such previous studies were similar to that of the results of the study. Slight differences may be derived from differences in type of machine utilized and assessors along with the degree of physical activity participated by the subjects.

Knee has been reported in a several studies so far. The results of a study with similar age groups with largest study subjects showed knee extension and flexion of 175 Nm and 96 Nm, respectively [18]. Such results were slightly higher than the results observed in this study. In another study, the extension and flexion strengths were 185 Nm and 95 Nm for men and 121 Nm and 59 Nm for women, respectively, which were close to the results of this study of respectively [13]. This study showed of knee extension and flexion strength of 187 Nm and 103 Nm for men and 103 Nm and 56 Nm for women, respectively. The isokinetic strength values so far have shown similar results especially for the general population with partially wide range of about 10%. However, error range of test-retest, possible differences in subject and surrounding conditions, and alterations to the assessor procedure could be explain such difference [19].

The second objective of this study was the proportion of muscle strength in the muscle group. Strength ratios are essential since they explain a large part of injury and can be utilized to prevent injury. A large amount of studies has been reported on the knee strength, however, studies on other areas are scarcely reported. Previous studies have suggested knee flexion to extension strength ratio of about .6 [20,21]. Also, similar strength between agonistic and antagonistic muscular strength is recommended for balanced movement and prevention of injury. In this study, the knee flexion to extension ratio was .55 and .54 for men and women, respectively, with slightly lower extension ratio. Ankle dorsiflexion to plantarflexion strength ratios were .30 and .29 for men and women, respectively. In previous studies, suggested ratios of .30 in men and .26 in women, respectively, were reported with recommended plantarflexion strength three times greater than that of dorsiflexion [4]. The ratio of ankle eversion to inversion strength ratio was .86 and .84 for men and women, respectively with inversion strength about 1.2 times stronger than that of eversion, according to a previous study. Such results were similar to that of the results of current study.

In the case of Hip, studies have been rarely conducted in either in Korea or in other countries. Unlike standardized assessment protocol on the knee flexion and extension strength measurement, hip strength could be assessed with the subject laying on the side or standing based on the intention of the examiner or the characteristic of the isometric machine. Depending on the study protocol, gravity correction may have been omitted. Regardless of the protocol, most of the studies reported similar abduction to adduction strength or about 20% showed either greater abduction strength or abduction strength [12,22]. In addition, Sugimoto et al. (2014) reported difference in 28 to 32% in results due to gravity compensation [23]. Gravity correction was also made in this study. Although abduction strength was similar to that of adduction strength, adduction strength was slightly higher. Raw data without the gravity correction showed mixed results between adduction and abduction strength. Such results indicate similar strength between adduction and abduction strength. Moreover, significantly high correlation factor of .84 indicate need for gravity correction through body weight.

The third purpose of the study involves observing correlation relationship of muscular strength between the hip, knee, and ankle joints (Table 4). Generally, muscular strength is proportional to muscle mass as well as body weight. Since all the tested joints in this study were weight bearing joints, weight must be considered. Muscle mass and muscle strength decrease, and body weight increases with advanced age. During the measurement process the joint axis is aligned to the axis of the isokinetic machine for correct application of the moment arm. Since the unit of torque or newton meter (Nm) is force perpendicular to the length of a moment arm, greater moment arm lead to greater strength given similarly given force. That is, greater the length of the muscle, greater force may be exerted with similar force. Comparatively greater length and mass of the thigh muscle may explain comparatively greater muscular exertion.

Previous studies did not observe the correlation relationship between strength of different joints. Greater rates of correlation were observed between joints in men than in women. Moreover, greater correlating relationships were observed between the hip and knee joints. That is, substantial to excellent correlations (r 〉 0₩.6) were shown between the hip and knee joints. Although significant correlations were observed with the ankle joint, such significances were mostly moderate. Such correlations may be due to several factors. However, majority factor for strong correlation may be due to overlapping muscles are activated for the hip and knee joints [24,25]. That is, one of the major agnostic muscles of the hip flexion and knee extension is quadriceps muscle. In addition, the major agnostic muscle of the hip flexion and knee flexion is hamstrings muscle. Although muscles such illiosoas and gluteus maximus also play role hip movement, a large amount of the joint movements rely on quadriceps and hamstrings. Such muscle sharing also occurs in other movements such as hip abduction and adduction. On the other hand, although the hip, knee, and ankle joints share similar kinetic chain and related movements, muscles involved in the ankle joint movements, plantarflexion and dorsiflexion, majorly rely on gastrocnemius and tibialis muscles, respectively. The major movers are independently activated from the major muscles of the hip and knee joints. In addition, the distance between the point of axis (the joint of the talus and the tibia) and the point of force (the point where the machine is connected with the person) is very short in the ankle. On the other hand, significant differences were shown in the areas with the greatest strength, which were knee extension and hip extension in both groups.

Overall, this study also compared the correlations between age. However, age did not show significant influence on the results of the strength. This may be due to the limiting age diversity of the subject groups. This is also a limitation of this study and aging factor should be further elucidated in the future study. Studies conducted with similar age groups in other countries showed similar test results as that of this study. Isokinetic strength assessment with close to 30 years of history seem to show constant results despite the influencing factors such as changes in subject physique and posture, assessment machine, assessment manual, and assessor variations. This may be possible due to automatic adjustment moment arm or gravity correction for relatively stable value.

There are several limitations to this study. One of the major limitations of this study is the limited number of participants, especially women. However, comparatively small standard deviation was observed with similar age, weight, and height ranges between the participants. Isokinetic results of comparable physique and age group may provide valuable results as reference value. Future studies should involve different age groups for reference values for each age and strength bracket. Offering values for commonly assessed joints and segment could provide valuable information for developing evidence-based rehabilitation program for related diseases. Providing minimal requirement for functional movement or threshold values could be valuable information for various areas including clinical setting.

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