RELATIONSHIP OF ISOKINETIC LEG STRENGTH AND 2 KM TIME TRIAL ON STATIONARY ROWING ERGOMETER AMONG MALAYSIAN MALE NATIONAL ROWERS

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Abstract

Background: Strength of leg musculature is crucial to generate propulsive force during rowing. The purpose of this study was to determine the relationship of isokinetic dominant leg strength and 2 km time trial on stationary rowing ergometer among male national rowers.

Methods: Seventeen male national rowers were recruited for the study. Their hip and knee isokinetic strength were determined in the sagittal plane at 60°/s angular velocity. The relationship between the hip and knee strength, and 2 km time trial performance were evaluated using Pearson correlation.

Results: The national rowers completed the 2 km time trial duration in 7.20±0.39 minutes. The hamstring to quadriceps ratio (H:Q) was significantly correlated to 2 km time trial performance (r=-0.491, p=0.045). No other significant relationships between hip and knee isokinetic strength and 2 km time trial performance were observed.

Conclusion: Increased isokinetic knee strength ratio (H:Q) may enhance 2 km time trial performance among male national rowers. Other isokinetic variables of hip and knee isokinetic strength were not significantly related to 2 km time trial.

Keywords: *Hip, Knee, Muscular Strength, Performance*

Introduction

Repetitive rowing motions consisted of coordinated muscle action with the initial portion of the drive demanding maximum leg power. Both the quadriceps and hamstring muscles extend the knee while soleus and gastrocnemius plantarflex the feet (1). While the muscle activity during early drive phase has resulted from the knee extensor muscles, the activity during early recovery phase is caused by hip flexors which include rectus femoris, psoas, iliacus, pectineus, and sartorius (2). Successful elite rowers produce about 75-80% and 20-25% of their stroke power from their legs and arms, respectively (3). Leg strength is correlated to rowing performance as the quadriceps provide most of the power during leg drive and pulling phase of the rowing stroke (4,5). Furthermore, hip and knee extensors are identified as the most important muscles for rowing propulsion (4,6). Therefore, leg muscles play an important role particularly in the force generation during the drive phase of rowing.

Leg strength can be determined by the torque produced on an isokinetic dynamometer (7). Peak torque is defined as the highest muscular force output at any moment during a repetition; it indicates the muscle's maximum strength capability (8). Meanwhile, peak torque/body weight (PT/

BW) is the normalised value of peak torque relative to body weight and expressed as a percentage. Lower limb muscle strength tests have mainly focused on the assessment of the knee joint (9,10). Few studies have been dedicated to the hip joint, for which testing position, range of motion, and stabilisation techniques have varied. Hence, this leads to discrepancies regarding the reliability of hip torque measures. Julia *et al*. (11) have reported an intraclass correlation coefficient (ICC) value of 0.94 for concentric hip flexion at 60°/s when tested in the supine position, whereas Arokoski *et al*. (12) have reported a value of only 0.70. These two studies have also shown dissimilar findings for hip extension, which can be explained by varied tested position and range of motion. Additionally, a certain ratio exists between the agonist and the antagonist group (i.e., hamstring to quadriceps ratio, H:Q) in order to protect the related joint (13). This ratio has been used to examine the hamstrings and quadriceps moment-velocity patterns, knee's functional ability and muscular strength balance (14). It is also a possible screening tool for predisposition to injury (15) and as a rehabilitative goal following injury (16).

In order to improve rowing performance, which is commonly evaluated as the time taken to complete 2 km rowing time trial, it is crucial to increase the lower limb muscular strength. Despite the importance of leg strength in rowing performance, their relationships were rarely studied in trained rowers. Hence, the current study was proposed to determine the relationship between isokinetic hip and knee strength and 2 km time trial on stationary ergometer among male national rowers.

Materials and Methods

Study design

This cross-sectional study consisted of two tests: 1) 2 km time trial and 2) isokinetic strength test for hip and knee in the sagittal plane (i.e., flexion and extension motions). Two kilometers time trial is a simulated race test commonly used to evaluate rowing performance (3,4). Each test took approximately one hour to be completed, including preparation time and was conducted with at least 24 hours interval between the tests. The purpose of the rest interval was to avoid fatigue between the tests. The sequence of the tests were randomised to reduce bias across the participants. During the tests, participants wore compression clothes, took a light meal at least two hours before the tests, and had at least six hours of sleep during the night prior to the tests.

A priori sample size calculation of Pearson correlation showed that 15 participants were sufficient to yield 80% power of the study with an effect size of 0.62. The effect size was based on Riechman *et al*. (17). Hence, 17 Malaysian male senior rowers aged between 18-25 years were recruited in this study. Only participants with at least one year of representing Malaysia in the national team were included. Rowers with current lower limb injuries and those with any serious musculoskeletal injuries that required surgery within the past year were excluded. The study protocol was approved by the Human Research Ethics Committee of Universiti Sains Malaysia (USM/JEPeM/17030194) and in compliance with the Declaration of Helsinki. Participants were informed of the experimental procedures and upon agreement of participation, their written consent was obtained. They provided information about their medical history and health conditions. The study was conducted at a sports science laboratory of a local university in September 2017. All data collection was completed in two weeks.

Study Procedure

Body weight (kg) and height (m) were measured with a digital scale (Seca 769, Hamburg, Germany) while body fat percentage was evaluated using Electronic Body Fat Percentage Analyser (Omron HBF-360, Kyoto, Japan). The dominant leg segments' length was measured with a measuring tape. The dominant standing leg length was quantified as the distance from the anterior superior iliac spine (ASIS) to the centre of the ipsilateral medial malleolus.

Next, participants wore a heart rate transmitter around their chest for their heart rates to be recorded via telemetry heart rate monitor (T61, Polar, Electro Oy, Finland). Then, they warmed up for three minutes on a stationary rowing ergometer (Concept 2 Model D, Morrisville, USA) with a preferred load. After warming up, the resistance (i.e., drag factor) was added based on the participants' body weight as recommended previously (18) for the 2 km rowing time-trial on Concept 2 ergometers. During the trial, the screen of the ergometer displayed the remaining metres, average duration for 500 m splits and accumulated time. The researcher verbally encouraged the rowers to complete the time trial in the shortest time possible. Time taken to complete the trial, heart rate (bpm), stroke rate (strokes per minute, spm), and stroke power (watts, W) were recorded. Then, participants cooled down on the ergometer by rowing with less resistance for approximately 5 minutes.

Following at least 24 hours after 2 km rowing time trial, each participant performed isokinetic strength tests to measure their muscular strength at the hip and knee joints during flexion-extension movements. The isokinetic tests were carried out using a dynamometer (Biodex 3 Multi-joint Testing and Rehabilitation System Biodex Medical System, Shirley, NY, USA). The test was preceded by a 5-minute warm-up on a cycle ergometer (Monark Model 818E, Sweden) at low intensity (i.e., 50 watts) at 60 RPM.

For isokinetic testing at the hip joint, the participant was placed in supine position on a test table. The axis of the dynamometer was aligned with the flexion-extension axis of the hip, whereas the support lever was fixed at the lower end of the thigh. The pelvis, trunk, and contralateral thigh were stabilised by straps. The test started with hip flexion from its neutral position. Familiarisation was conducted prior to the data collection. At an angular velocity of 60°/s, participants performed three sets of eight repetitions at maximal concentric hip flexion and extension. Peak torque at this velocity is a representative of work and power for the isokinetic muscle performance test of the extensor and flexor muscles of the knee and hip (19). A minute of rest interval was provided between the sets.

For isokinetic testing at the knee joint, the participant was seated with 90° hip flexion. The hip and trunk were held steady by stabilising straps, while the support lever was fixed at a point between the upper two-thirds and the lower third of the leg. The participant was strapped into the testing position after the depth of the seat, the height of dynamometer, and the length of the support lever were adjusted. The test was initiated from 90° of knee flexion. Three sets of eight repetitions for the knee flexion-extension test were conducted at 60°/s of angular velocity, with one-minute rest interval between the sets. All tests on the dynamometer was performed on the dominant leg. Peak torque was expressed as Newton metre (Nm). Time-to-peak torque (ms) is a measure of the time from the start of a muscular contraction to the point of the highest torque development. This value is an indicator of the muscular ability to produce torque quickly. The higher the time-to-peak torque, the more torque will be produced; due to the nature of eccentric muscle physiology. The normalised value of peak torque relative to body weight (PT/BW) and hamstring to quadriceps ratio (H:Q) were calculated.

Statistical Analysis

Statistical analysis was performed using statistical software (SPSS version 22, Chicago, IL). Distribution of data was checked by the Shapiro-Wilk test. Descriptive data for physical characteristics were presented as mean ± standard deviation (SD). Pearson correlation was used to determine the relationship between 2 km time trial and isokinetic leg strength. A statistically significant correlation was indicated by a probability value of less than 0.05. The strength of the relationship was based on the scale recommended by Portney and Watkins (20).

Results

Physical characteristics of participants are presented in Table 1. Participants completed the 2 km time trial in 7.20±0.39 minutes with a mean stroke rate of 29.1±2.86 spm and mean stroke power of 298.6±63.95 W. The relationship between time trial and stroke rates (r=-0.229, p=0.492) and stroke power (r=-0.265, p=0.492) were not statistically significant.

Table 1: Physical characteristics of participants (N=17)

Physical characteristics	Mean ± SD
Age (years)	19.1±2.0
Experience in competitive rowing (years)	2.7±0.9
Height (cm)	173.3±3.09
Weight (kg)	72.06±6.0
BMI (kg/m²)	23.7±1.3
Body Fat (%)	18.3±6.0
Fat Mass (kg)	13.6±3.23
Hip circumference (cm)	23.4±2.0
Dominant Thigh circumference (cm)	17.3±1.04
Dominant Shank length (cm)	44.1±2.0
Dominant Thigh length (cm)	49.4±6.1
Dominant Shank to Thigh Ratio	0.91±0.16

cm=centimeter
kg=kilogram
%= percent

Table 2 and 3 present the peak torque per body weight (PT/BW), time-to-peak torque and ratio of isokinetic hip and knee strength tested at 60°/s in the sagittal plane (i.e., extension and flexion motions) of the dominant leg, respectively. The tables also include Pearson's correlation coefficients (r) and the statistical significance of the correlation, p-value. No significant relationship was observed between any isokinetic hip strength variables and 2 km time trial on stationary ergometer among male rowers (Table 3). Only the H:Q was significantly correlated to 2 km time trial (r=-0.491, p=0.045) (Table 3).

Table 2: Descriptive statistics and relationship between isokinetic hip peak torque per body weight, time-to-peak torque, and hip flexor to extensor to strength ratio and 2 km time trial (N=17)

Variables	Mean ± SD	r	p-value
Peak Torque/BW (%)			
Flexion Dominant Leg	116.8±29.8	0.187	0.473
Extension Dominant Leg	181.3±76.9	0.116	0.658
Time-to-peak Torque (ms)			
Flexion Dominant Leg	377.7±148.5	0.033	0.901
Extension Dominant Leg	395.5±158.3	-0.064	0.808
Strength Ratio			
Hip Flexor:Hip Extensor	1.62±0.73	0.042	0.879

Table 3: Descriptive statistics and relationship between isokinetic knee peak torque per body weight, time-to-peak torque, and knee flexor to extensor strength ratio (H:Q) and 2 km time trial (N=17)

Variables	Mean ± SD	r	p-value
Peak Torque/BW			
Extension Dominant Leg	268.12±33.7	-0.778	0.122
Flexion Dominant Leg	134.4±31.5	-0.240	0.354
Time-to-peak Torque (ms)			
Extension Dominant Leg	515.2±101.1	-0.480	0.051
Flexion Dominant Leg	786.7±310.9	0.697	0.509
Strength Ratio			
Knee Flexor: Knee Extensor (H:Q)	2.1±0.5	**-0.491***	**0.045**

* indicates significant relationship

Discussion

In this study, the participants generated isokinetic hip extension PT/BW for the dominant leg (181.3±76.9% at 60°/s) which was within the normal range for hip extension in the supine position (21). Our findings showed that PT/BW for hip extension of the dominant leg was not significantly correlated to 2 km time trial, although several researchers have stated that leg strength was correlated to rowing performance particularly the thigh muscles as the main power sources during rowing (4,5,24,25). The drive phase is the major part of a rowing stroke; hence, it demands maximal power from the leg, particularly the hip extensors such as gluteus and hamstring muscles (22). During the end of the drive phase, as knee flexors are nearing the completion of their extension movement, the hip is also extending by the contraction of the gluteus and hamstring muscles (23). Moreover, the hip and knee extensors are identified as the most important muscles for propulsion (4) and primary elements of stroke power among elite rowers (24). The discrepancy of findings between the current and previous studies could be due to the different methods used in evaluation of muscular strength and power. The current study used isokinetic strength test while the previous studies (4,5,24,25) applied electromyography (EMG) analysis to determine muscular strength. EMG could provide details of muscle activity of a specific muscle during investigated motions while isokinetic device tested the muscular strength in a group of muscles.

Our results showed that the PT/BW for isokinetic knee flexion for the rowers was 134.4±31.5% at 60°/s which was within the normal range during knee flexion (21). It has been demonstrated that the maximal force and muscular power of knee flexors are greater in rowers compared to non-rowers with similar muscle morphology (24). Furthermore, our findings showed that time-to-peak torque in extension and flexion of the dominant knee was not significantly correlated to time to completion of 2 km time trial. This means that the ability to generate peak torque at quicker rate is not related to faster completion of 2 km time trial. The reason of evaluating only the dominant side is because the dominant knee showed greater isokinetic strength tested at 60°/s compared to the non-dominant knee in young adult men (26) and the high index of waveform similarity for rowing-related muscles indicated that muscle activity was symmetrical bilaterally during rowing on sculling ergometer among untrained subjects (27) and trained male rowers (28).

Greater H:Q ratio was moderately related to faster 2 km time trial (Table 3) except for H:Q ratio. Three muscle synergies were observed while rowing on ergometer with the main synergy consisted of leg muscles (27,28). The biarticular thigh muscles, rectus femoris of quadriceps and biceps femoris of hamstring, are crucial during rowing on ergometer to transfer force generated from the stretcher to the trunk (24,25). Also, the leg muscle synergy was shown significantly associated with rowing economy (28) which means that by emphasizing on the leg drive, force transfer between the joints can be done effectively (24,27). Leg drive can be enhanced by increasing the muscular strength of the muscles particularly the biarticular muscles (27,28). Therefore, we recommend that coaches and athletes work to improve the strength of the agonists and antagonist leg muscles (i.e., hamstring and quadriceps) in order to boost the 2 km time trial performance.

We observed that, in trained male rowers, only H:Q ratio was correlated to the performance of 2 km time trial. However, the findings of the study are limited to 2 km time trial conducted on a stationary ergometer among male rowers of national level (i.e., highly trained rowers but not elite level). Also, muscular strength was tested using an isokinetic device which was not able to provide details of strength for each specific lower limb muscles. The isokinetic test was conducted only in sagittal plane motions (i.e., knee flexion and extension). It was shown previously that there were minor motions of the knee joints in transverse (i.e., internal and external rotations) and frontal planes (i.e., knee adduction and abduction) (29,30), which were not accounted for in the current study. We recommend to include isokinetic strength testing in these planes for future studies.

Conclusion

Isokinetic knee strength ratio (H:Q) in male rowers showed significant moderate correlation with 2 km time trial. However, other isokinetic variables of hip and knee strength were not significantly related to 2 km time trial performance. Rowers and coaches should focus on developing a balanced muscular strength of agonist and antagonist knee flexors (i.e., hamstrings and quadriceps) in order to enhance rowing performance.

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Competing interests

The authors have no conflicts of interest to declare.

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