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Research article

MEASURING PEAK ANGULAR VELOCITY OF KNEE EXTENSION DURING UNLOADED KICKING: A PILOT STUDY

Zulezwan A. Malik[1,2], Jos Vanrenterghem[2] & Jatin G. Burniston[2]

[1]Faculty of Sports Science and Coaching, Universiti Pendidikan Sultan Idris, Perak, Malaysia
[2]Research Institute for Sport & Exercise Sciences, Liverpool John Moores University

Abstract

Journal of Sports Science and Physical Education 5(2): 9-14, 2016 - Jump squat tests can be used to investigate the differences in the force - velocity (f-v) profile in movement that is more a sport-specific than isolated exercises such as open chain leg extension. However, squat jumps involve multi-joint movement, making it questionable which muscle is the main contributor for the movement. The main aim of this study is to develop a test of isolated knee extension that encompasses the entire range of human f-v relationship and to investigate the correlation between linear encoder and kinematic measurement of angular velocity using a camera system during unloaded kicking. One healthy male subject volunteered to participate in the study and performed 10 unloaded kicks (knee extension). A cuff was strapped around the lower leg, approximately 2 cm above the medial malleoli and connected to a linear velocity encoder (MuscleLab Ergotest version 4010, Norway). During the test sessions, three-dimensional motion analysis was performed with an Oqus Motion Capture System (Qualisys, Sweden). Data were transferred to Windows-based data acquisition software (Qualisys Track Manager). There was a positive linear relationship ($r = 0.94$). The unloaded kicking test to determine maximum angular velocity at knee extension measured using the QTM showed that the mean angular velocity was $362^{\circ}.s^{-1}$, with the highest value being $528^{\circ}.s^{-1}$. This preliminary study suggests isokinetic dynamometry (IKD) can be used to investigate the entire range of velocities (i.e isometric – velocity maximum) of knee extension in normal human subjects. Further studies can examine the use of IKD in measuring higher velocities.

Keywords: Isokinetic dynamometry, jump squat, f-v relationship

Introduction

Jump squat tests can be used to investigate differences in the f-v profile in movement that is more a sport-specific than isolated exercise such as open chain leg extension (e.g. Cormie et al., 2010). However, squat jumps involve multi-joint movement, making it questionable which muscle to biopsy. Therefore we chose a simpler model of knee extension using isokinetic dynamometry (IKD). Pilot work was undertaken to find a way to measure f-v in an isolated joint. An appropriately positioned linear encoder can be used to calculate knee angular velocity during unloaded kicking to find the suitable velocity on isokinetic dynamometer device.

Isokinetic testing was conducted using isokinetic dynamometer (Multi-Joint System 3 Pro; Biodex Medical Systems, New York, USA). The device controlled the velocity of joint flexion or extension by applying variable resistance throughout the range of motion. The velocity of joint rotation is constant, excluding acceleration to and deceleration from the designated velocity and the force is dependent on how hard the individual pushes against the load cell (Huang et al., 2003). It can be used at low, moderate and high velocities depending on the different evaluations or programs and provides reliable data.

Isokinetic exercises may possibly be superior because of certain aspects, such as providing objective data, reliability, and creating the possibility of variations in the preparation of exercise programs (De Lateur, 1996). Data acquisition and analysis have been improved by using computer systems interfaced to isokinetic dynamometers. Recently developed computer systems provide correction for gravitational and inertial errors, accurate computation of isokinetic parameters and real-time display of the torque output.

This pilot study tried to develop a test of isolated knee extension that encompasses the entire range of human f-v relationship. The aim of this preliminary study was to establish a simple technique for measuring peak angular velocity of knee extension during unloaded kicking and to determine the maximum angular velocity of the knee during unloaded. Besides that, this study was conducted to investigate the correlation between linear encoder and kinematic measurement of angular velocity using a camera system during unloaded kicking. If successful, this technique could provide a simple measurement of maximum velocity.

Methodology

Participants

One healthy male subject volunteered to participate in the study and performed 10 unloaded kicks (knee extension) at different velocities in order to determine maximum angular velocity at knee extension.

Procedure

Angular velocity, acceleration, moment of force, and power development during maximal unloaded knee extension were determined using ProReflex Motion Capture System (Qualisys, Sweden) (Figure 1). Ten maximal unloaded knee extensions were performed at varying velocities separated by rest periods of 30 s. Trials with a visible countermovement were discarded. A cuff was strapped around the lower leg, approximately 2 cm above the medial malleoli and connected to a linear velocity encoder (MuscleLab Ergotest version

4010, Norway). Average velocity (AV) was recorded during each kick. The lower leg is allowed to move freely. The subject was instructed to extend their right knee "as fast as possible" into a kicking pad (Fig.2). The movement range was from 90° knee flexion, which is the relaxed starting position, to ~5–10° from full extension. During the test sessions, three-dimensional motion analysis was performed with an Oqus Motion Capture System (Qualisys, Sweden). Twelve markers were used in total for dynamic trials (Iliac crest, knee medial epicondyle, knee lateral epicondyle, upper leg proximal anterior and posterior, upper leg distal anterior and posterior, lower leg proximal anterior and posterior, lower leg distal anterior and posterior, maleolus lateral) and attached on the right side. Data were transferred to Windows-based data acquisition software (Qualisys Track Manager). This system includes an advanced optoelectronic camera system that produces clean and accurate 3D data and also recording velocity. All modelling and analysis was undertaken in visual D (v.4.83, C-Motion, Germantown, MD, USA) using geometric volumes to represent segments (Hanavan, 1964) based on cadaver segmental data (Dempster, 1955).

Figure 1: Leg in rest position

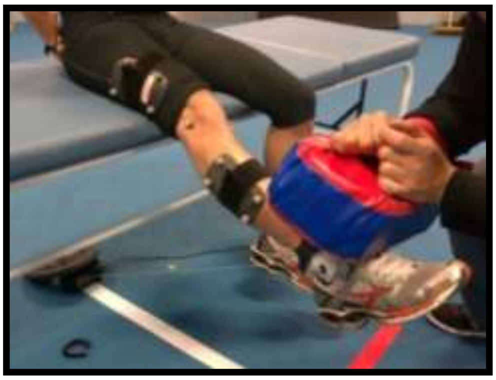


Figure 2: Leg extended to kicking pad.

Results

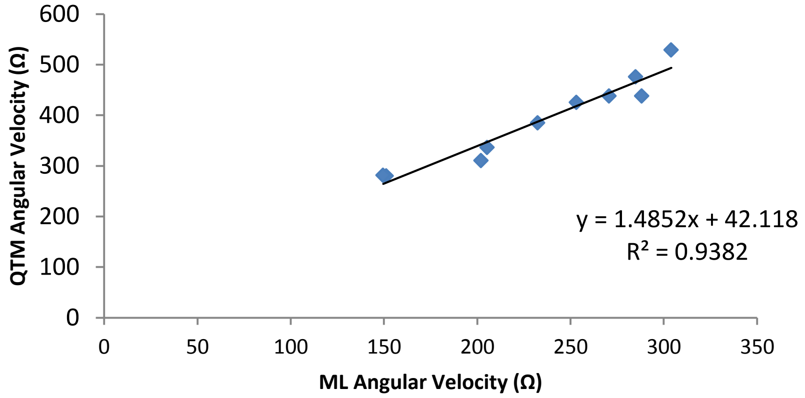
Calculation of velocity

The data from MuscleLab are in meter per second linear velocity. To compare between the camera systems, which that gives angular velocity, MuscleLab data need to be converted into angular velocity. Angular velocity equal to theta (degree/one radian=57.2958) multiplied length of subject's leg in meters.

Velocity (m/s)	(/)ℓ In meter	ω (sec x 57.2958)	Peak angular velocity (degree/sec)
1.46	0.36	4.06	232.4
1.27	0.36	3.53	202.1
0.95	0.36	2.64	151.2
0.94	0.36	2.61	149.6
1.29	0.36	3.58	205.3
1.59	0.36	4.42	253.1
1.79	0.36	4.97	284.9
1.81	0.36	5.03	288.1
1.70	0.36	4.72	270.6
1.91	0.36	5.31	304.1

Table 1: Data from MuscleLab and conversion to angular velocity.
Equating angular velocity, v=ωxℓ. Equating velocity on linear speed, v=m/s where v=velocity, m=meter, s=second, ω=angular speed, ℓ=length (subject's leg) Each one of the degree represent one kick or attempt.

Velocity correlation of unloaded kick test using MuscleLab and Qualisys Track Manager is shown in Figure 3. Correlation coefficients measure the strength of association between two variables. There was a positive linear relationship which the correlation coefficient at 0.9382.



ML	232.4	202.1	151.2	149.6	205.3	253.1	284.9	288.1	270.6	304.1
QTM	384.6	310.3	280.2	280.9	336.4	425.4	475.5	438.1	438.1	528.9

Figure 3: Correlation between ML and QTM

Discussion

Hence, measurement of linear displacement using MuscleLab can be used to measure angular velocity at knee during maximum unloaded kicking. However we note that peak angular velocity was below 500˚.s^{-1}, which is within the range of velocities that can be measured by Biodex 3 isokinetic dynamometry. Therefore a further study was conducted to investigate whether IKD was capable of measuring the entire range of velocities in an untrained population.

The unloaded kicking test to determine maximum angular velocity at knee extension measured using the QTM showed that the mean angular velocity was 362˚.s^{-1}, with the highest value being 528˚·s^{-1}. Because the Biodex software only allows to measure power when the prescribed velocity is reached, the maximum pre-selected angular velocity of 450˚.s^{-1} was chosen for the test protocol, to ensure most participants can achieve that speed and power data will be recorded.

The preliminary work suggests isokinetic dynamometry can be used to investigate the entire range of velocities (i.e. isometric – velocity maximum) of knee extension in normal human subjects. Therefore it is not necessary to use a separate analysis technique (unloaded kicking). However it was still necessary to prove that IKD is a reliable measurement tool across this range of velocities because from other studies report IKD at any velocity > 300˚.s^{-1}. Also it was still unknown whether there is a correlation between IKD knee extension and Max power (or similar) during vertical jumping, i.e. external validity.

Previous work (Iossifidou et al., 2005) has reported a correlation of power generation between knee extension IKD and the squat vertical jump performance. Iossifidou et al., (2005) measured knee joint power generation during a concentric knee extension isokinetic test and a squat vertical jump and they found a stronger correlation at the highest velocities (300˚.s^{-1}). However, there is a large difference in knee angular velocity and peak power between squat vertical jump which typically > 450˚.s^{-1} and knee extension at 300˚.s^{-1} IKD. For example, significant differences were found between knee joint power in the two tests performed by Iossifidou et al., (2005) to trained basketball player and track and field athletes (squat vertical jump: 2255 ± 434 W; isokinetic knee extension: 771 ± 81 W).

Several studies (Aragon & Gross, 1997; Bobbert et al., 1986) investigated joint kinematics during jumping found that knee angular velocity during vertical jump was approximately 15 rad.s^{-1}, which is equal to 860˚.s^{-1}. However, in interpreting the relationships, the squat vertical jump involves both legs and is also influenced by the action of the biarticular muscles and there is a combined transfer of energy between joints. So the velocity during isolated knee extension is likely to be less. Meanwhile isokinetic tests involve one joint and are limited to certain muscles (e.g. quadriceps). In the current work the results showed peak angular velocity was <500˚.s^{-1} for IKD knee extension.

This contrast with Andersen et al., (2005) that reported changes in the human muscle f-v relationship during training and detraining, and found peak unloaded kicking angular velocity detraining was ~ 800˚.s^{-1} measured by flexible goniometer. This maybe because the two methods they used not worked the same way with current study, being compared to a linear velocity encoder or motion capture system as used in the current study. Differences in subjects that were used also determined a huge difference where the present study just use sedentary people compared to Andersen et al., (2005) that involved trained athletes.

Therefore, we were trying to develop a test of isolated knee extension that encompasses the entire range of human f-v relationship and also we interested to know whether aspect of IKD performance correlate with whole body jump performance.

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Zulezwan A. Malik
Faculty of Sports Science and Coaching,
Sultan Idris Education University,
Tg Malim, Perak
E-mail: zulezwan@fsskj.upsi.edu.my