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Original Research Article

The Correlation between Quadriceps and Hamstrings Strength in the Dominant Leg with Decision-Making Time during Cutting Manoeuvres in Planned and Reactive Agility Tests

Yaser Hamed Alamri

MPT (Sports), Physiotherapist, Prince Sultan Military Medical City Riyadh-KSA

ABSTRACT

Study Objective: The Correlation between Quadriceps and Hamstrings Strength in the Dominant Leg with Decision-making Time during Cutting manoeuvres in Planned and Reactive Agility Tests.
Method and Measurements: Twenty-five healthy active participants took part in the study. The five Vector sensitive mats and Vector laptop were the equipment used to measure the decision-making times, which designed by the school of Healthcare Sciences at Cardiff University, while the Hand-Held Dynamometer was used to measure the isometric quadriceps and hamstrings strengths. Other equipment were used; tape measure, weight scale, height scale were used; duct tape was used to prevent the sensor mats from sliding on the floor. All participants involved in five agility drills for each planned and reactive agility tests, and then followed by three isometric quadriceps and hamstrings measures.
Results: The Intraclass correlation coefficient (ICC) calculated and revealed a moderate ICC value of Planned Decision-Making Times (PDMT) and low ICC value of Reactive Decision-Making Times (RDMT) (0.420) and (0.189), respectively. The ICC calculated for Isometric Quadriceps Strength (IQS) and Isometric Hamstrings Strength (IHS) showed fair values (0.319) and (0.402), respectively.
Conclusion: No strong relationship has revealed between all variables, with the strong reliability of each device to be considered as valid and reliable machines. More research needs to be conducted on the relationship between isometric quadriceps and hamstrings strength and between agility performances.
Key Words: Correlation, Quadriceps, Hamstrings

INTRODUCTION

The fitness of any player relies on a certain level of agility that includes different components. For players for whom agility determine the athlete's level of performance, many researchers have tried to find a proper definition of agility that involves all the influences that affect it. [1-6] Nevertheless, the most acceptable definition, and at present the most comprehensive concept, of agility is "a rapid whole-body movement with change of velocity or direction in response to a stimulus". [6]

Agility can be performed according to the category of the activity. Two main types of agility can represent its performance: change of directional speed (CODS), [3,7] and reactive agility. [6,8] The difference between the two types is represented in the availability of anticipation and decision-making factors, which are very important for good, agile performance and for conducting a proper cutting manoeuvre. [6] Moreover, decision-making time is a crucial element that positively affects any player's task. Decision-making time is considered a component of reactive agility. [8]

In order to measure the relationship between agility and the strength of the quadriceps and hamstrings, a hand-held

dynamometer is a good choice. It requires less than four minutes to get the results and requires little skill to use. [9] Moreover, a strong relationship has been revealed between the measured strength of the quadriceps and hamstrings and the agility of athletes, [10] which explained the recommendations of many authors to use this measured strength for evaluating the performances of players. Different research has discussed the benefit of measuring the strength of hamstrings and quadriceps, especially for football players, in post-injury evaluation. [11,12]

The purpose of this study is to investigate the effect of the strength of the quadriceps and hamstrings of the dominant leg on a cutting manoeuvre and to find whether any correlation exists between muscle strength measured isometrically and an agile performance.

MATERIALS AND METHODS

Subjects: 25 participants from schools at Cardiff University, a coffee shop barista, and a gym employee. An invitation to participate in the study and considered appropriate for data collection with a standard deviation of 0.05, while 80% power was used with a clinically relevant difference of 10% and a medium effect size of 0.50. Convenience sampling was based on the previous calculation, despite this being a pilot study. [13] Ethical approval was obtained from the Research Ethics Committee at the School of Healthcare Sciences, Cardiff University, in July 2014.

Design: A cross-sectional study design and healthy subjects were chosen in order to investigate the correlation between muscle strength of the dominant leg and DMT – the time between a visual cue and the subject acting – when performing a cutting manoeuvre. [14] This procedure involved the use of two agility tests, RAT and PAT. This study thus aimed to determine whether the performance levels were comparable in all healthy subjects. Isometric strength of the quadriceps and hamstrings, which are the main muscles that control the knee joint in a cutting manoeuvre, were also measured. [15]

Inclusion and Exclusion Criteria:

Inclusion Criteria: [16]

Age range-19-36 years. Moreover, to ensure that participants were able to perform the entire task and all required manoeuvres, they were assessed as level II subjects on the Sport Activity Rating Scale below.

Table 1: Sports Activity Rating Scale

Level	Frequency of Play	Sports	Points
Level I	4–7 days per week	Jumping, hard pivoting, cutting (basketball, volleyball, football, soccer, gymnastics)	100
		Running, twisting, turning (racquet sports, baseball, hockey, skiing, wrestling)	95
		No running, twisting, jumping (running, cycling, swimming)	90
Level II	1–3 days per week	Jumping, hard pivoting, cutting (basketball, volleyball, football, soccer, gymnastics)	85
		Running, twisting, turning (racquet sports, baseball, hockey, skiing, wrestling)	80
		No running, twisting, jumping (running, cycling, swimming)	75
Level III	1–3 times per month	Jumping, hard pivoting, cutting (basketball, volleyball, football, soccer, gymnastics)	65
		Running, twisting, turning (racquet sports, baseball, hockey, skiing, wrestling)	60
		No running, twisting, jumping (running, cycling, swimming)	55
Level IV	No sports possible	ADL with no problems	40
		ADL with moderate problems	20
		ADL with severe problems	0

The subjects were recruited by sending emails to postgraduate and undergraduate students at Cardiff University as well as other Saudi students studying at the University. Recruiting university students and Saudi students in Cardiff was the most appropriate approach because of the time limitations of the study.

Exclusion criteria: [17,18]

- Age <18 or >45 years
- History of lower limb injuries that might affect performance.
- Recent lower limb injury

- Current pain or effusion in the lower limbs.
- History of cardiac problems
- Audio or visual problems
- History of pulmonary problems
- Inability to provide informed consent
- Any physical pain that could influence performance.

Equipments & Measuring Tools:

The equipment used during the study included- five vector sensor mats, laptop, bespoke software for recording task and contact times from the wireless transmitters on the mats, which were relayed via a central receiver attached to the laptop, two light bulbs to serve as visual cues for participants. This set-up was designed at the School of Healthcare Sciences, Cardiff University. Hand-held dynamometer (HHD), tape measure, weight scale, height scale, duct tape was used to prevent the sensor mats from sliding on the floor. Cones were used to indicate a starting point and for the T-tests. [19]

Procedure:

The study was conducted at the Research Centre for Clinical Kinesiology. The procedure started with sending the information sheets to all participants two days before the test. The subjects were asked to wear shorts and trainers suitable for the experiment, i.e. a PAT, RAT, and IMS measurement. When the subjects arrived, the consent forms were handed out to be read and signed. The demographic data collected was weight, height, and age. In order to determine each subject's dominant leg, they were asked to stand erect and kick a ball thrown to them by the researcher. By observing which leg started to move towards kicking the ball, it was possible to detect the dominant leg. [18]

At this point, to decrease test bias, standardised instructions were given out to ensure that all participants received the same information. [20] The researcher then performed a demonstration test. The subjects were instructed to step on all of the mats, to follow the directions given verbally before starting to run, and to perform the cutting manoeuvre on mat C prior to ending on either mat E1 or E2. The participants were then asked to stand at the starting point and to be ready for the commands. All the participants underwent trial familiarisation via three repetitions of the RAT, which also served as the warm-up. [21] The participants then rested for five minutes to prepare themselves for the real trial. [18] However, it is important to note that the simplicity of the task as demonstrated to the participants might not reflect similar movements in ordinary sporting conditions, and this point could have an impact on the validity of the results achieved. [22, 23]

First, the participants performed the PAT: they stood at the starting point and waited for the command to start running ("Go"). All subjects performed five trials in accordance with the directions set by the researcher: three to the right and two to the left. For the RAT, they performed five repetitions of the same task without any directions but they were free to choose the end mat they should go to after stepping on mat B and receiving the visual stimulus, before performing the cutting manoeuvre on mat C.

Isometric muscle measurements (IMMs) were taken using an HHD, which is a reliable tool for assessing knee muscle strength. [24,9] Three IMMs were taken for the right quadriceps, left quadriceps, right hamstrings, and left hamstrings while the subjects were sitting on an adjustable bed to ensure proper positioning. According to, [24] the proper position for isometric quadriceps strength (IQS) measurement is in an upright sitting position with both the hip and the knee in a 90° flexion (Figure 1), while [25] claimed that the prone position is the most suitable to gain an accurate isometric hamstring strength (IHS) measurement (Figure 2).

Figure1. Isometric Quadriceps Strength Measurement

Figure2. Isometric Hamstring Strength Measurement

Data Analysis:

Reliability of the Statistical Analysis:

In order to gain the degree of repeated measures at the same visit, all the results utilised in this research were calculated separately. To measure the reliability of the results, the intraclass correlation coefficient (ICC) was obtained using the Statistical Package for Social Sciences (SPSS student version 20) software; the level of significance was set at 0.05. A two-way mixed model was needed, as this research is for test-retest reliability. All the data was measured at the same visit and combined with a confidence interval (CI) of 95%.

The ICC that was used for the DMTs was recorded during the cutting manoeuvre, which was performed in the PAT and RAT and also for the IQS and IHS for the dominant leg of the subjects. When using the ICC classification system, [26] with a range from 0 to 1, the closer the value to one, the higher the reliability (see table 2).

Table2. ICC Classification System

ICC Value	Classification
0.00–0.20	Slight reliability
0.21–0.40	Fair reliability
0.41–0.60	Moderate reliability
0.61–0.80	Substantial reliability
0.81–1.00	Excellent reliability

Statistical Analysis of the Correlation Study Data:

In order to analyse the demographic data of the study population, descriptive statistics (means, standard deviation and ranges) were used, and the average of five scores was considered. The participants' performance during the PAT and RATs was used to measure the PDMT and reactive DMT (RDMT); the relationship between the PDMT and RDMT with the IQS and HIS of the dominant leg was analysed using Pearson's product moment correlation coefficients (*r*) test. The level of significance was set at 0.05. Also, the analysis of the entire statistical data was conducted using the Statistical Package for Social Sciences (SPSS) software (student version 20).

RESULTS

The relationship between the DMT to do the cutting manoeuvre in PATs and RATs and the isometric muscle strength measurements for quadriceps and hamstrings in the dominant leg was investigated in active healthy participants using a Vector machine and an HHD. The reliability (test-retest) test for each individual measurement parameter was conducted and provided separately.

Demographics Data:

In all, 25 active healthy male subjects, aged between 19 and 36 years, who met the required criteria agreed to take parts in the experiment. Descriptive statistics for the 25 participants' characterised are provided to give a clear

and brief idea of the demographic data (Table 3). As mentioned previously, regarding activity level, this study used the sports activity rating scale. [16] All 25 subjects were classified as level II (Table 1). According to the table, which described the levels by the activity duration of the subjects, all subjects were categorised under level II in the scale, meaning they had the ability to perform sports activities 1 to 3 days per week.

Table3. Demographic Data

	N	Minimum	Maximum	Std. Deviation
Age	25	19	36	5.305
Weight	25	54	98	11.737
Height	25	158	182	5.336

Reliability of the Results:

The intraclass correlation coefficient (ICC) was calculated for deducing the planned decision making time (PDMT) and the reactive decision making time (RDMT) using the measurements for the IQS and IHS obtained from the Vector machine and hand-held dynamometer (HHD), respectively. Based on five measurements for each participant in one visit, the ICC and a Confident Interval of 95% for every single test of the research are tabulated (Table 4). The PDMT during PAT had a moderate ICC value (0.420), whereas the RDMT during the RAT showed a low ICC value (0.189) (Table2). However, with regard to the IMMs, both the IQS and IHS showed fair values (0.319 and 0.402, respectively). The most reliable measure was the PDMT, as it had a moderate ICC value, while on the other hand, the RDMT was considered the least reliable measure owing to its low ICC value (0.189).

Table 4. Intraclass Correlation Coefficients

		95% Confident	Interval
Measure	ICC	Lower Bound	Upper Bound
Planned Decision Making Time (PDMT)	0.420[a]	0.240	0.626
Reactive Decision Making Time (RDMT)	0.189[a]	0.040	0.404
Isometric Quadriceps Strength (IQS)	0.319[a]	0.073	0.576
Isometric Hamstrings Strength (IHS)	0.402[a]	0.155	0.642

In summary, the acceptable ICC values were reported for most of the parameters that had been investigated during the five experiments for the PDMT, RDMT and during the three trials analysing the IQS and IHS measures analysed. Therefore, as a good reliability level had been obtained from the previous explanations, the PDMT, RDMT, IQS, and IHS can be considered reliable measurement apparatus.

Correlation Results

Using the Pearson's product moment correlation coefficient (*r*), a correlation test was performed for the PDMT and RDMT with the IQS and the IHS measures, respectively, of the 25 subjects. A correlation test was also carried out to determine the correlation between PDMT and RDMT. The average PDMT and RDMT values for five successful trials during the cutting manoeuvre in the PATs and RATs were calculated. For the isometric muscle strength measurements, the average of three readings for the IQS and IHS were taken separately. Table 5 below shows the correlation results between the average values of PDMT and RDMT and the average values of IQS and IHS, respectively. The correlation between the average values of the PDMT and RDMT was also noted.

Table 5. Correlation Results

	r value	Sig. (two-tailed)
PDMT vs. IQS	-0.064	0.761
PDMT vs. IHS	0.366	0.072
RDMT vs. IQS	0.126	0.547
RDMT vs. IHS	-0.041	0.844
PDMT vs. RDMT	-0.254	0.221

Relationship between planned decision-making time and isometric quadriceps strength measure:

In order to investigate the relationship between planned DMT (PDMT) and the IQS, Pearson's product moment correlation coefficients (*r*) test was performed. No significant relationship between PDMT and IQS was noted, as the p-value was 0.761 (>0.05). Figure 3 shows that there is no relationship between the

cutting manoeuvre during the PAT and IQS values among the subjects' performances (r = -0.064), suggesting that the subjects with stronger quadriceps isometrically did not necessarily perform the change-of-direction faster in a PAT.

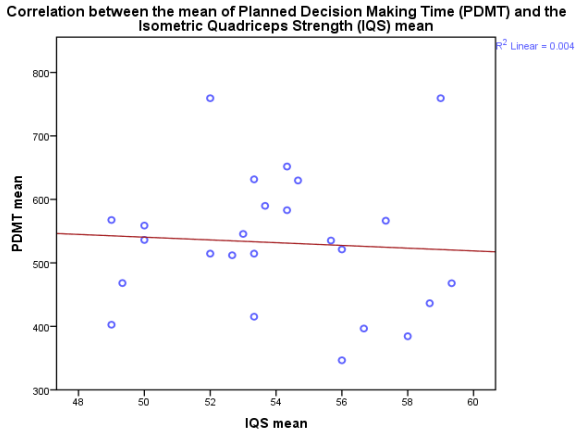

Figure 3. Scatter-plot of the relationship between PDMT and IQS

Relationship between Planned Decision Making Time and Isometric Hamstrings Strength Measure:

The Pearson correlation coefficients (*r*) test was performed to determine the relationship between PDMT and IHS. A weak positive relationship was noted between PDMT and IHS (p = 0.072). Figure 4 shows that a weak positive relationship exists between the cutting manoeuvre during PAT and IHS value (*r* = 0.366), suggesting that the participants who had stronger hamstrings isometrically may perform the change-of-direction better in a PAT.

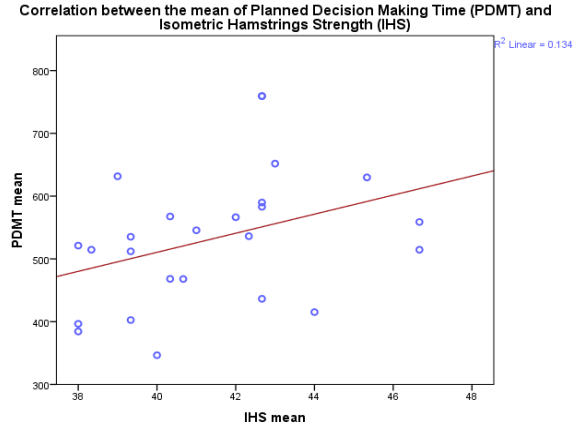

Figure4. Scatter-plot of the relationship between PDMT and IHS

Relationship between Reactive Decision Making Time (RDMT) and Isometric Quadriceps Strength Measure:

The Pearson's correlation coefficients (*r*) test was used to discuss the relationship between RDMT and IQS. There is no significant relationship between the RDMT and IQS when the p-value = 0.547 (>0.05). Figure 5 shows that there is no relationship between the cutting manoeuvre during the RAT and IQS among subjects' performances (r = 0.126), indicating that the participants who had stronger quadriceps isometrically did not perform the change-of-direction faster in a RAT.

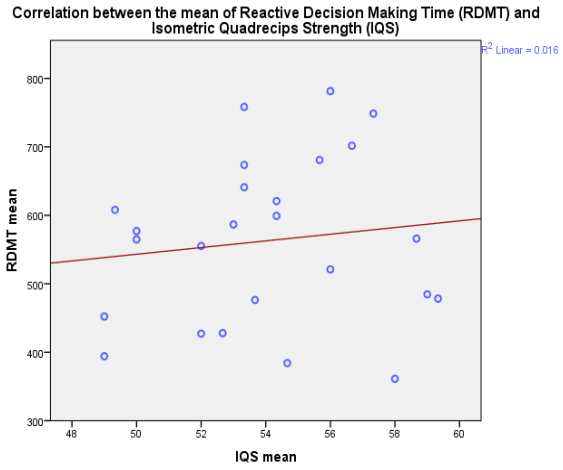

Figure5. Scatter-plot of the relationship between RDMT and IQS

Relationship between Reactive Decision-making Time and Isometric Hamstring Strength Measure:

The Pearson's correlation coefficients (*r*) test was performed to determine the relationship between RDMT and IHS. There was no relationship between RDMT and IHS (p = 0.844). Figure 6 shows that there was no relationship between the cutting manoeuvre during the RAT and IHS among the subjects' performances (r = -0.041), suggesting that the participants who had stronger hamstrings isometrically did not perform the change-of-direction faster in an RAT.

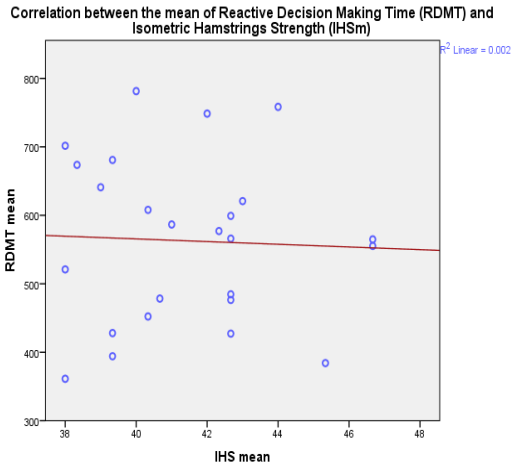

Figure6. Scatter-plot of the relationship between RDMT and IHS

DISCUSSION

Isometric Muscle Measurement:

The analysis of the previous findings resulted in fair value in ICC classification of reliability for isometric quadriceps and hamstrings strengths measurements. In this part the discussion of H01 and H02 will take place.

The analysis of the results was classified according to. [26] When more than 0.6 is the value of the ICC classification, the test will be considered as a reliable, while when the value is less than 0.6 the hypothesis will be rejected. Both measurements had ICC values less than 0.6. Isometric quadriceps strength and isometric hamstrings strength have fair ICC values of 0319 and 0.402, respectively. And from that, the ICC value represent IQS and IHS using HHD are not very significant. Proofed a strong reliability of using hand-held dynamometry for isometric muscle strength measurements for knee flexion and extension while positioned in 30° knee flexion. [25] However, the methods of measuring the quadriceps and the hamstrings may was unideal to the test. The methods used in this study used belt connected to the HHD and all the participants' positions for knee extension and flexion were from upright setting and prone position, respectively. In addition, in both positions the measurements were taken when the subjects' knees in 90° flexion.

Relationship between IQS and IHS with PDMT:

This part of the discussion will investigate the results of the study that related to the literature review H01 and H02. The warm-up that conducted prior to the test was used and successfully considered as a proper warming-up, which was aimed to reduce the chance of injury during the tests and gain the best possible accuracy. The relationship between isometric quadriceps strength and planned decision-making time with a value of r = -0.064, which is very low correlation. Moreover, as a result of that, there is no relationship between isometric quadriceps strength measurement and cutting manoeuvre during PAT. Similarly, the relationship between isometric hamstrings strength and planned decision-making time with a value of r = 0.366, which is very week relationship, too, which means there is no relationship between isometric hamstrings strength measurement and cutting manoeuvre during PAT. The participants were required to run the planned agility test with certain speed and performance five successful trials. All subjects were told the speed and the direction that they should go to after performing change of direction. Also, three Isometric quadriceps and hamstrings strength measurements were taken in proper position using reliable device. The first explanation of the results gained is the positions of the subjects and knee angle during measuring the isometric muscle strength were not the most reliable positions to be tested from. Another explanation is the shaped of the agility test was not T-test as reported in previous studies, but was a modified one with a Y shape drill.

Relationship between IQS and IHS with RDMT:

This part of the discussion will investigate the findings of the study that related to H01 and H02 represented in literature review. Warming-up that carried out successfully by all participants before the test conducted and used a proper and

evidenced method. The aim to conduct that method of warming-up is to reduce the possibility of having injured during the tests and to enhance the best possible test accuracy. The relationship between isometric quadriceps and hamstrings strength measurements with the reactive decision-making time is very week, with value of r = 0.126 and r = -0.041, respectively. Therefore, no relationship could be found between the isometric quadriceps and hamstrings strength measurements and between the cutting manoeuvres during RAT. However, all instructions that related to the speed and performance were given carefully to all the subjects. The reaction to the light stimulus was random and chosen by the machine, which let all participants take few more milliseconds to decide which direction they will choose and perform change of direction (cutting) manoeuvre. Proper and recommended warming-up were conducted before beginning the tests. One reason explains the results in the study is the method of measuring the isometric quadriceps and hamstrings strength, the positions of the subjects and knee angles were not the most reliable position to measure from. Other explanation is the T-test that used in previous research, was modified in the study to Y-shape drill.

Relationship between Cutting Manoeuvre and Dominant Leg:

This part of the discussion would investigate the findings that related to H03 and H04 mentioned in literature review. With considering all participants are right dominant legs as they asked to stand erectly and kick a ball. The first leg moved to kick the ball was considered the dominant leg. [18] Instructions were given to all subject and they required to start the cutting manoeuvre by any leg they find proper for them. As all of them begin the change of direction movement by using their dominant leg, this give a good relationship between the cutting manoeuvre and the dominant leg. That means, when the subjects perform appropriate warming-up and having good instructions, their perception will be in the best situation and they can do movements perfectly. However, the variation of the findings that resulted among planned decision-making times and reactive decision-making times, show no relationship between the dominant leg and the better planned and reactive agility performance.

Comparison with previous studies results:

Different influences that affect the agility performance of the players was discussed in the previous studies represented in the literature review. The most essential elements for agility are perception and decision-making time. These are the considerable factors in this research, as they can help athletes to conduct cutting manoeuvre. Furthermore, in the old literature, anticipation abilities and decision-making capabilities are strong factor to gain better agility performance. Players can perform differently due to their anticipation and reaction to stimuli, while they divided into high skilled and low skilled athletes. To differentiate between both levels' groups, previous studies used a variety of stimuli systems, ranges from auditory and visual. In this study and seeking for the accuracy of the performances, flash light was used.

Moreover, the researches reviewed regarding the isometric muscle measurement showed the reliability of this test for strength and the relationship with agility. However, strong relationship revealed between isometric quadriceps and hamstrings strength with the agility performance, very few researches have discussed this issue.

Clinical Implications:

As a result of what has been discussed, using hand-held dynamometer is a good method in evaluation the athletes before exercises and after treatment. It is an easy method and applicable to use in clinic with considering the proper position to get correct readings.

Using the pressure sensitive mats for measuring agility is very useful, while it is

mimic the real situation of sports tasks that can be formed in different sport patterns. Moreover, for what to be consider as an advantages, this machine is very accurate that it has the ability to measure the time by milliseconds.

Study Limitations:

There are some limitations related to this study including subjects' position during isometric quadriceps and hamstrings strength testing and speed.

Subjects' position during isometric muscle strength testing:

Ties Measuring muscle strength is very important for assessment purposes before activities or after treatment in order to be qualify for sport application. The method of positioning during measuring isometric quadriceps and hamstrings strength that used was not strongly reliable with relation to agility performance. [24,25] It has been recommended to measure quadriceps and hamstrings isometrically while flexing the knee by 30° to gain valid results. This position is strongly related to the agility performance and it has been proofed clinically. [9]

Speed:

There is an affect factor for successful agility performance, while it is not working alone. The concept of speed has different factors which help to improve it to conduct better and faster performance. Dynamic unity, muscle elasticity, drive technology and positive or negative condition specific resistance are the factors that affect speed. A combination of these influences would work together to improve speed and there for improve agility performance. Nevertheless, the change of the speed during agility and the instability in conducting steady speed through the whole running tasks will affect the relationship between all variables.

CONCLUSION

The return to sport successfully and the good preparation of any exercise need a proper method to test the muscle strength. Because of the importance of agility performance and the level that produce better patters, measuring muscle strength is essential in this issue. Moreover, a proper method and device should be chosen for this purpose in order to gain a reliable reading for muscle strength. All that for achieving the best agility performance in sports.

The study was performed to investigate the relationship of the isometric quadriceps and hamstrings strength measurement with planned and reactive decision-making times during cutting manoeuvre in reactive and planned agility tests. From the recommendation to measure the decision-making time which suggesting to have an essential influence on agility test, [6] this study discussed cutting manoeuvre from the point of decision-making time. The results mentioned above reveal no significant relationship between different variables except a very week relationship between planned decision-making time and isometric hamstrings strength. As a result of that, no effect noticed of planned and reactive decision-making times on cutting manoeuvre. Nevertheless, the influence of dominant leg performing the faster and better cutting manoeuvre was invalid, too. However, the idea of starting cutting manoeuvre using dominant leg is correct. Future research need to re-consider subject's positioning during isometric muscle strength measure and proper knee angle.

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