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The Effects of Step Versus Jump Forward Lunge Exercise Training on Muscle Architecture among Recreational Badminton Players

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Abstract: *Background:* Previous studies have demonstrated the existence of relationship between muscle architecture and performance and how training could alter the architecture of muscles. *Objective*: The purpose of this study is to determine and compare the effects of step versus jump forward lunge training on muscle architecture among badminton players. *Materials and Methods:* Thirty recreationally active badminton players (mean age = 22.07 ± 1.39years old) volunteered to participate and were divided into three groups; i) jump forward lunge (JFL), ii) step forward lunge (SFL) and iii) control group (CG). Muscle thickness, pennation angle and fascicle length of vastuslateralis (VL), vastusmedialis (VM), rectus femoris (RF) and biceps femoris (BF) were tested pre- and post-training intervention. *Results*: Results showed both treatment groups (SFL and JFL) had their muscle architectures significantly changed in the post-test compared to the pre-test. JFL had significantly greater improvement in muscle thickness of VL, VM and RF and also pennation angle of VM compared to SFL. *Conclusion*: Overall, JFL was found to be superior in altering muscle architectures of the lower body compared to SFL training.

Key words: Muscle architecture・Step forward lunge・Jump forward lunge・Badminton・Lower body

INTRODUCTION

Previous studies have demonstrated the existence of relationship between muscle architecture (Figure 1) and performance and how training could alter the architecture of muscles (e.g. fascicle length, muscle thickness, pennation angle etc.) [1-6]. Among the types of training that have been investigated was resistance training in which has been shown to cause certain changes in muscle architecture [1-4, 6-8]. As such, study by Nimphius, McGuigan [9] showed strength training cause several changes to muscle architectures including muscle thickness and these changes were related to relative strength and speed improvements among female athletes.

In studying the muscular architectural adaptations, it has been shown this variable's adaptations to be training-specific. For example, Kawakami, Ichinose, Kubo, Ito, Imai, & Fukunaga [10] has shown the slow-heavy load training to improve muscle pennation angle and fascicle length. In contrast, fast-light load training has not shown any change or decrement in muscle pennation angle [11].

To date, there is lack of study that has determined the muscle architecture adaptation as the effects of lunge exercises. In contrast to squat exercise that has been used in training program and had been studied widely, most movements in sports involve an athlete to do a forward step so that one foot is in front of the other.

Badminton is one of the sports that involved a lot of lunge movement in the game [12]. The important of lunge in a game could be seen when the player want to retrieve a drop shot where the player need to do a deep lunge to get to the shuttlecock. Sturgess and Newton [13] had highlighted the importance of the ability to accelerate from receiving stance to retrieving a drop shot.

Due to the relevance of lunge movementin sport, lunge training are recommended to be included in strength and conditioning program. However, in order to achieve desired outcomes, the lunge training could be adjusted as different lunge training have also demonstrated different adaptations [14]. The different of adaptations could be attributed to several factors such as different in structural adaptations [5] imposed by the different stimuli that was caused by the different methods of training.

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Note the importance of muscle architecture on performances [5, 15, 16], it is the aim of this study to determine and compare the effects of step and jump forward lunge on lower body muscle architecture among badminton players.

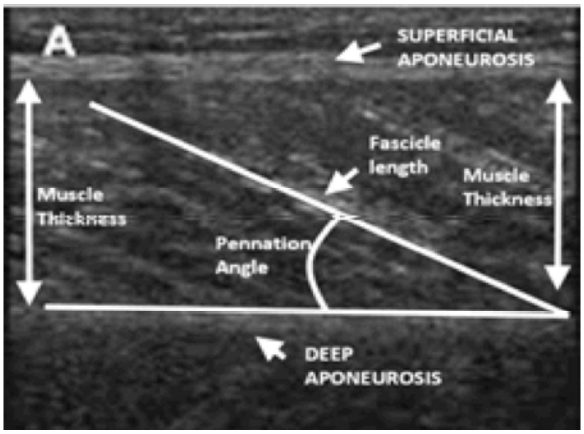

Fig. 1: Muscle architecture of vastuslateralis

MATERIALS AND METHODS

Participants: Recreational male badminton players (mean age: 22.07 ± 1.39 years old) were recruited as study participants. Participants recruited were currently active participating university level badminton tournament, training badminton for three (3) times a week and had been actively playing for at least 1 year. Participants were screened prior to testing using PAR Q. Each participant had read and signed an informed consent for testing and training approved by the UniversitiPendidikan Sultan Idris and the Thaksin University Ethics Committee (CODE E 060/2559). Each participant self-reported that they were familiar with jumping movement but had never involved in any systematic physical training.

Procedures

Step and Jump Forward Badminton-Specific Lunge: Figure 2 showed the step for SFL and JFL. Participants were instructed to stand while carrying a barbell with 30% 1RM loadings placed on their shoulder, feet shoulder width apart. Participants lunged forward and must lower the thigh to be parallel with the ground and then returned back to the starting position. Participants were needed to make a big step as during downward position, the knee should not extend beyond the toe. The non-leading lower limb must not move from its starting position and the head were constantly faced forward. As to simulate the movement used in real badminton game situation, participant bent their trunk to 45°forward. Jump forward lunge were performed by the JFL group. The movement was similar to the step forward lunge except participants need to explosively (jump) lunged forward and then explosively (jump) returned back also by jumping to the starting position.

(a)

(b)

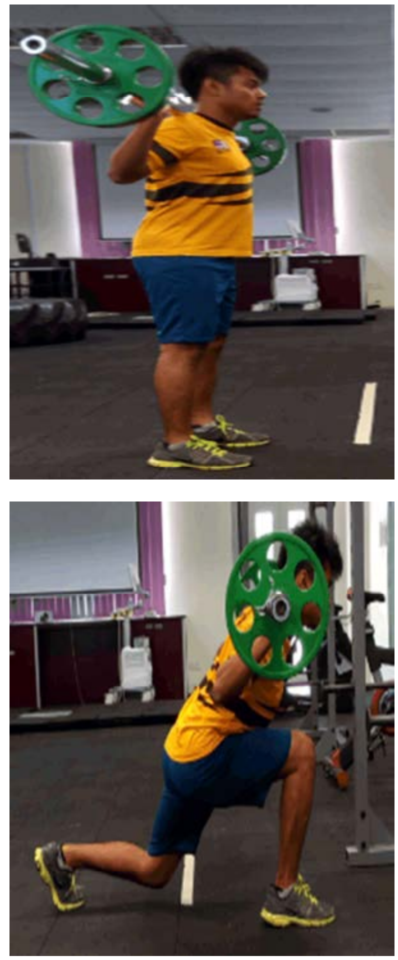

Fig. 2: (a) Starting and Ending phase of SFL and JFL in this study
(b) Middle phase of SFL and JFL in this study

Resting Muscle Measurement: Ultrasonography method was used to measure muscle thickness, fascicle length and pennation angle of VL, VM, RF and BF. These muscle architectures were measured using B-mode ultrasonography (F37, Aloka, Ltd, Tokyo, Japan) on the participant's self-reported dominant side.

The probe positioning was maintained with equal contact pressure during all measurements. The measurement of VL, VM and RF muscle thickness and pennation angle were done while the subject lying supine with leg straight [17, 18]. The BF muscle architectures were determined while the subject lying prone with leg straight [19, 20]. All measurements were taken while the leg was in resting position.

Based on the muscle thickness and pennation angle, fascicle length was calculated based on the equation used in previous study (Equation 1). All ultrasound measurement was performed by the same researcher. Figure 1 showed the example of image taken during ultrasonography.

Equation 1: Fascicle length = Muscle thickness/sin (pennation angle)

Data Collection: All participants involved in familiarization session in order to make sure all the participants were able to perform all the training exercises correctly. After familiarization session, participants were tested for their badminton specific forward lunge one repetition maximum (1RM). The 1RM test score were used as determinant of training loads during this study.

Participants involved in 8 weeks lunge training to determine and compare the effects of each training on muscle architectures. These two studies were started with familiarization sessions in which participants were briefed on how the tests and training sessions to be conducted.

All the lunge technique were closely monitored and controlled throughout all sessions. All lunge movement during the training were performed as fast as possible to simulate the real game situation. All the training and data collection sessions were supervised by the researcher with the assistance of appointed trained trainers. All sessions were conducted at the Physical Conditioning Lab, UPSI, TanjongMalim.

Training Programs: Both the SFL and JFL were required to perform the lunge training with 30% of their 1RM lunge value that were obtained during the pre-test. The intensity (30% 1RM) was chosen because this intensity allowed participants to maintain the fast and explosive movement that mimics their real movement during the game. All the participants performed the training for three sessions per week for eight weeks. During each session, participants need to perform six sets consisting of 20 repetitions per set (10 for each lower limb). The control groups do not involved in any resistance training program, but just continued with their daily lifestyle.

Statistical Analysis: Descriptive statistics were used to measure the mean and standard deviation of each physical characteristics and data scores. Repeated measures MANOVA was used to examine differences in muscle architecture in the pre- and post-training intervention within groups and the percentages changes between groups Statistical significance were accepted at an α-level of $p \leq 0.05$. All statistical analyses were conducted using SPSS version 23 (IBM, New York, USA).

RESULTS

Table 1 showed tha physical characteristics of participants

Table 1: Physical characteristics of participants

Variables	Mean ± SD
Age (years)	22.07 ± 1.39
Body Mass (kg)	70.07 ± 1.88
Body Weight (N)	687.41 ± 13.53
Height (cm)	173.13 ± 2.12
1RM (kg)	71.87 ± 2.59
Relative 1RM (1RM/BM)	1.03 ± 0.01

Table 2 showed the pre- and post-test data of the muscle architectures variables investigated in this study. Analysis on each group had found significant main effects were existed in all the muscle thickness (MT), pennation angle (PA) and fascicle length (FL) of SFL thus showed that SFL group has significantly increased all the muscle architectures investigated in the post test when compared to the pre-test: I) VLMT, $F(1,9) = 123.484$; $p < 0.001$, ii) VLPA, $F(1,9) = 27.563$; $p < 0.01$, iii) VLFL, $F(1,9) = 24.467$; $p < 0.01$, iv) VMMT, $F(1,9) = 129.706$; $p < 0.001$, v) VMPA, $F(1,9) = 27.562$; $p < 0.01$, vi) VMFL, $F(1,9) = 7.097$; $p < 0.05$, vii) RFMT, $F(1,9) = 272.842$; $p < 0.001$, viii) RFPA, $F(1,9) = 77.786$; $p < 0.001$, ix) RFFL, $F(1,9) = 18.226$; $p < 0.01$, x) BFMT, $F(1,9) = 138.273$; $p < 0.001$, xi) BFPA, $F(1,9) = 13.966$; $p < 0.01$ and xii) BFFL, $F(1,9) = 17.824$; $p < 0.01$.

As in SFL group, significant main effects were also found among JFL group, thus showed all MT, PA and FL of JFL has also significantly improved in the post test when compared to the pre-test: i) VLMT, $F(1,9) = 351.486$; $p < 0.001$, ii) VLPA, $F(1,9) = 34.005$; $p < 0.01$, iii) VLFL, $F(1,9) = 16.805$; $p < 0.01$, iv) VMMT, $F(1,9) = 73.50$; $p < 0.001$, v) VMPA, $F(1,9) = 81.001$; $p < 0.001$, vi) VMFL, $F(1,9) = 16.772$; $p < 0.01$, vii) RFMT, $F(1,9) = 532.023$; $p < 0.001$, viii) RFPA, $F(1,9) = 7.306$; $p < 0.05$, ix) RFFL, $F(1,9) = 11.897$; $p < 0.01$, x) BFMT, $F(1,9) = 152.220$; $p < 0.001$, xi) BFPA, $F(1,9) = 37.727$; $p < 0.001$ and xii) BFFL, $F(1,9) = 10.878$; $p < 0.05$.

No significant main effects were found for all the muscle architectures in the control group, i) VLMT, $F(1,9) = 1.374$; $p > 0.05$, ii) VLPA, $F(1,9) = 3.183$; $p > 0.05$, iii) VLFL, $F(1,9) = 3.710$; $p > 0.05$, iv) VMMT, $F(1,9) = .036$; $p > 0.05$, v) VMPA, $F(1,9) = 0.060$; $p > 0.05$, vi) VMFL, $F(1,9) = 1.466$; $p > 0.05$, vii) RFMT, $F(1,9) = 7.628$; $p > 0.05$, viii) RFPA, $F(1,9) = 7.875$; $p > 0.05$, ix) RFFL, $F(1,9) = 5.661$; $p > 0.05$, x) BFMT, $F(1,9) = 2.710$; $p > 0.05$, xi) BFPA, $F(1,9) = 2.359$; $p > 0.05$, xii) BFFL, $F(1,9) = 0.471$; $p > 0.05$.

Table 2: Muscle architectures in the pre- and post-training intervention

MA	Test	SFL	JFL	CG
VLMT	Pre	2.38 ± 0.07	2.36 ± 0.05	2.38 ± 0.08
	Post	2.43 ± 0.07*	2.45 ± 0.05*	2.38 ± 0.07
	% Diff	1.98 ± 0.58^{bc}	3.60 ± 0.61^{ac}	0.31 ± 0.81^{ab}
VLPA	Pre	16.85 ± 0.86	18.07 ± 1.70	17.51 ± 1.42
	Post	16.99 ± 0.87*	18.26 ± 1.86*	17.42 ± 1.47
	% Diff	0.83 ± 0.51^{c}	1.051 ± 2.55^{c}	-0.53 ± 0.94^{ab}
VLFL	Pre	8.22 ± 0.23	7.67 ± 0.59	7.93 ± 0.42
	Post	8.32 ± 0.25*	7.86 ± 0.69*	7.99 ± 0.47
	% Diff	1.18 ± 0.74	3.74 ± 2.77^{c}	0.84 ± 1.39^{b}
VMMT	Pre	2.59 ± 0.07	2.60 ± 0.06	2.60 ± 0.07
	Post	2.62 ± 0.06*	2.68 ± 0.07*	2.60 ± 0.08
	% Diff	1.36 ± 0.40^{bc}	3.24 ± 1.24^{ac}	-0.05 ± 0.63^{ab}
VMPA	Pre	16.69 ± 0.89	16.66 ± 0.93	16.74 ± 0.96
	Post	16.83 ± 0.89*	16.96 ± 0.10*	16.72 ± 0.92
	% Diff	0.85 ± 0.54^{b}	1.79 ± 0.58^{ac}	-0.10 ± 1.51^{b}
VMFL	Pre	8.98 ± 0.36	9.09 ± 0.29	9.12 ± 0.26
	Post	9.08 ± 0.32*	9.22 ± 0.34*	9.06 ± 0.26
	% Diff	1.08 ± 1.31	1.43 ± 1.09^{c}	-0.67 ± 1.79^{b}
RFMT	Pre	1.83 ± 0.09	1.86 ± 0.09	1.84 ± 0.10
	Post	1.88 ± 0.09*	1.966 ± 0.09*	1.82 ± 0.12
	% Diff	2.62 ± 0.44^{bc}	5.49 ± 0.85^{ac}	-0.97 ± 1.11^{ab}
RFPA	Pre	12.56 ± 1.30	12.67 ± 1.48	12.55 ± 1.27
	Post	12.78 ± 1.30*	13.01 ± 1.41*	12.41 ± 1.44
	% Diff	1.76 ± 0.60^{c}	2.79 ± 3.01^{c}	-1.22 ± 1.38^{ab}
RFFL	Pre	8.45 ± 0.52	8.56 ± 0.58	8.50 ± 0.47
	Post	8.52 ± 0.48*	8.79 ± 0.57*	8.52 ± 0.49
	% Diff	0.90 ± 0.69	2.73 ± 2.59	0.26 ± 0.35
BFMT	Pre	2.47 ± 0.11	2.49 ± 0.12	2.48 ± 0.12
	Post	2.52 ± 0.12*	2.57 ± 0.12*	2.46 ± 0.14
	% Diff	2.09 ± 0.50^{bc}	3.18 ± 0.80^{ac}	-0.75 ± 1.45^{ab}
BFPA	Pre	14.94 ± 0.76	15.04 ± 0.72	15.04 ± 0.89
	Post	15.09 ± 0.80*	15.44 ± 0.72*	14.95 ± 0.95
	% Diff	1.00 ± 0.86^{bc}	2.67 ± 1.46^{ac}	-0.62 ± 1.29^{ab}
BFFL	Pre	9.57 ± 0.14	9.59 ± 0.15	9.55 ± 0.13
	Post	9.68 ± 0.11*	9.64 ± 0.13*	9.54 ± 0.12
	% Diff	1.13 ± 0.84^{c}	0.55 ± 1.25	-0.14 ± 0.66^{a}

[a] = significantly different from SFL
[b] = significantly different form JFL
[c] = significantly different from CG
* = significantly different from pre-test

DISCUSSIONS

Several findings in the previous studies have shown the existence of relationship between muscle architecture and performance and how training could affect the architecture of muscles (e.g. fascicle length, muscle thickness, pennation angle etc.) [1-6]. Among the types of training that have been investigated was resistance training in which has been shown to cause certain changes in muscle architecture [1-4, 6-8].

In this study, the effects of SFL versus JFL on muscle thickness, pennation angle and fascicle length of vastuslateralis (VL), vastusmedialis, (VM), rectus femoris (RF) and biceps femoris (BF) were examined by using ultrasonography method. All muscle architectures of SFL and JFL were shown to be significantly increased during post-test compared to pre-test. No significant different were found for all the muscle architectures in the control group.

Analysis on each of the muscle showed that for VL muscle architecture, both treatment groups (SFL and JFL) had significantly greater changes of muscle thickness (VLMT), $p < 0.001$ and pennation angle (VLPA), $p < 0.01$ compared to CG. JFL had greater improvement in VLMT, $p < 0.01$ compared to SFL. Percentage changes of VLFL among JFL was shown to be significantly greater compared to CG, $p < 0.01$. For vastusmedialis muscle architecture, both treatment groups (SFL and JFL) had significantly greater changes of muscle thickness (VMMT), $p < 0.01$ compared to CG while JFL had greater improvement in VMMT, $p < 0.01$ compared to SFL. The percentage changes of VMPA was greater in JFL compared to SFL and CG, $p < 0.01$ while JFL also was shown to have greater percentage changes of VMFL compared to CG.

For rectus femoris muscle architecture, both treatment groups (SFL and JFL) had significantly greater changes of muscle thickness (RFMT), $p < 0.001$ and pennation angle (RFPA), $p < 0.001$ compared to CG. JFL had greater improvement in RFMT, $p < 0.01$ compared to SFL. For biceps femoris muscle architecture, both treatment groups (SFL and JFL) had significantly greater changes of muscle thickness (BFMT), $p < 0.01$ and pennation angle (BFPA), $p < 0.001$ compared to CG. JFL had greater improvement in BFMT, $p < 0.01$ and BFPA, $p < 0.001$ compared to SFL. SFL was found to have greater percentage changes of BFFL compared to CG.

The mechanical and metabolic stresses imposed by resistance training are believed to influence changes in muscle size [21-23]. In this study, the mechanical stress imposed by both training groups demonstrates gains in the lower body muscle thickness. With respect to gross measures of muscle thickness, SFL and JFL significantly increased muscle thickness of the lower extremities. In comparison to a traditional hypertrophy protocol of 6-12 repetitions per set [24], the SFL and JFL condition produced gains in thickness of the vastuslateralis, vastusmedialis, rectus femoris and biceps femoris. These results were in contrast to the generally recommendation of at least 65% 1RM loading to induce hypertrophy [25-27].

The finding of this study was in line with that found by Alegre, Jiménez [28] in terms of muscle thickness and fascicle length but was in contrast in terms of pennation angle. Alegre, Jiménez [28] reported an increment in the vastuslateralis thickness and a decrement in pennation angle, as a result of explosive resistance training. Among the factors that might account for increment of fascicle length in the training group are the specific adaptations of muscle architecture as a result of lunge training and/or the mechanical stimulus over the muscles during the training. Although it is only a speculative that increment of fascicle length in humans is a result of mechanical stimulus, but it has been observed in animal muscles [29].

Muscle's size will probably affects its force generating capacity. Although no specific muscle size was investigated in this study, findings has showed that all the muscle architectures investigated in this study (muscle thickness, pennation angle and fascicle length) were increased among training groups. Despite the increment of muscle thickness shown in this study, muscle thickness in this study was only investigated at the mid belly of the muscle but not at the proximal and distal part. Blazevich, Gill [11] found that muscle thickness increment was greatest at proximal muscle sites. Thus, more study is needed regarding the adaptations to specific sites of muscles.

While several previous studies has reported an increase in fascicle angle in response to slow-heavy loading training [11, 30, 31], this current study along withEarp, Newton [6] found that fascicle angle will increase after plyometric training (JFL). Besides that,similar to previous study [11], this current study found an increase in fascicle length as a result of fast-light load training,however, JFL was shown to be more effective to increase fascicle angle among healthy untrained participants.

This current study was the first to examine the muscle architectures' adaptations to different lunge protocols training in recreational badminton players and the results demonstrate the effectiveness of both protocols in altering muscle architectures.

CONCLUSIONS

Results demonstrated the superiority of jumping forward lunge training compared to step forward lunge in enhancing muscle architectures. Findings of this study demonstrate how the muscle structure adapt to different training exercises which will be a good reference for the selection of exercises to be implemented by various sports as possibility exists that different muscle architecture could be advantages for different sports or movements.

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