J Int Acad Phys Ther Res 2020; 11(3): 2147~2154
ISSN 2092-8475

www.iaptr.org
https://doi.org/10.20540/JIAPTR.2020.11.3.2147

Comparisons of Increased Repetitions and Exercise Intensity of the Symmetric Upper Limbs between Men and Women

Background: Improperly conducted exercise may lead to worsening of musculoskeletal complications. Such may worsen due to increased repetition and intensity during exercise. In addition, different responses may show different needs for training program.
Objectives: To compare kinematics of symmetric concentric and eccentric motions during increased repetitions and intensities for men and women.
Design: Quasi-randomized trial.
Methods: A total of ten men and eleven women participated in this study. Concentric and eccentric motions of the lateral raises were observed for initial positions of abduction and adduction. Low and high exercise intensities were applied, and 15 repetitions were conducted for both intensities. Initial, 3 in-between repetitions, and last repetition were recorded for comparisons.
Results: The concentric or abduction motions showed no significant differences for all comparisons. However, eccentric or adduction motions showed greater significant differences as the exercise intensity increased for both men and women. Such significant differences were most prevalent during the first and last repetitions with greatest differences during the initial repetitions.
Conclusion: Kinematic difference between men and women during increased repetitions and intensity indicate the need for more individualized exercise intervention and consideration between men and women. Individualized interventions may prevent exercise-induced postural abnormality and corresponding musculoskeletal dysfunction.

Keywords: *Repetition; Fatigue; Exercise intensity; Asymmetry*

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Received : 17 June 2020
Revised : 25 July 2020
Accepted : 03 August 2020

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INTRODUCTION

Improperly performed exercise may lead to difference in musculature and muscular strength between symmetric bodily area such as between limbs. Properly balanced musculature between paired area or side have been known to prevent postural imbalance and progression to dyskinesia.[1-4] Maintaining similar kinematics seems vital in maintaining healthy musculoskeletal system. Although physical activity is known to prove healthy musculoskeletal system and needed muscle strength for quality daily life and perform athletic activity, improperly performed exercise may lead to postural and strength imbalance between symmetric sides.[4-8]

Previous studies which compared dominant and non-dominant sides reported of kinematic differences during symmetric motion. Repeated motions led to imbalanced motions between the dominant and non-dominant sides in athletes who utilize dominant side more that non-dominant side.[5] Such imbalance usage of one side over the other may lead to problems in the musculoskeletal system by excessively activating one side and suppressing the other side.[5]

Repeated motion and intensity by great weight load have been known to influence local musculatures and muscular strength. Repeated motion and increased intensity have been known to promote fatigue and alterations in the kinematics.[9] Increased fatigue by the musculature system has been known to reduce the control ability to produce detailed motion.[10,11] Previous studies rarely considered the effects of increased fatigue in muscular control between men and women. Men comparatively have different response to fatigue.[9] Such physiological difference should be observed during similar fatigue environment for proper exercise intervention.

Shoulder joint is the most complex area along human body. Slightest changes in kinematics may influence muscular imbalance between dominant and non-dominant shoulders and arms.[2,4,6] Therefore, this study compared kinematic differences between left and right upper limbs during symmetric motions of abduction and adduction for men and women for prevention of postural problem and corresponding musculoskeletal complications.

SUBJECTS AND METHODS

Subjects

The study was approved by the Inha University Ethics Committee and performed according to the Declaration of Helsinki. Twenty-one right-handed participants without clinically significant shoulder pain or dysfunction were first recruited from the campus. All participants were meticulously explained of the purpose and procedure of the experiment before the examination. Verbal and written informed consents were obtained from the participants to participate in the study.

Twenty-one right-handed subjects were composed of ten males and eleven females with mean ages of 22.9 (±1.29) years and 21.36 (±2.87) (P=0.13) years and mean body mass index (BMI) of 22.9 (±2.48) and 20.7 (±1.62) kg/m2 (P=0.04), respectively. The participants were grouped into men and women groups. The men and women groups regularly participated in physical activity 1.7 (±1.91) and 2.8 (±2.44) (P=0.24) days per week and 32.0 (±36.15) and 36.4 (±38.80) (P=0.79) minutes per day, respectively. Each bout of exercise was divided into beginning, middle, and final.

Experimental procedure

Experiment was performed at least 2 hours after small-sized meal. The participants were also prevented from participating in high loaded physical activity. Lateral raise motions were performed by an expert in exercise for proper and similar performance by all participants based on previous study.[12]

Questionnaires

General information on the participants were obtained through pre-organized questionnaires. BMI (body mass index) was calculated with provided weight (kg) and height (cm) and age (years) was calculated by date of birth. General health status and physical activity information were also obtained questionnaires. The dominant side was determined by questionnaire and the Edinburgh Inventory. Participants with scores of more than 6 or above were included in the study.[13,14]

Lateral raises

Lateral raises were explained and shown to the participants as follows. The movements were started from the erected position with the arms extended straight and slightly apart from the center line of the body (zero degree) to about 10 degrees. Each dumbbell was held by each hand with the palms facing the body and feet were spread a shoulder wide apart from the mid-line of the body.[8] Both arms were abducted from the shoulder joint and the range of motion from the initial abduction position to the initial adduction position of 100 degrees. The initial abduction position is the starting position of the lateral raise, from ten degrees to slightly raised above 100 degrees. The initial adduction position is the lowering position of the lateral raises by the limbs.

The participants were asked to perform the lateral raise motion with continuously constant motion without sudden motional changes. The lateral raises with abduction and adduction motions were performed repeatedly for 15 more times. Lateral raises that were not performed to full range of motion or less than 70 degrees were not counted.[15]

Six dumbbells weighing from 1 kg to 6 kg were prepared. Prior to actual performance by the participants, the weights were selected based on low (≤40% of 1-RM) and high (75~85% of 1-RM) intensity based on one repetition maximum calculation method.[16,17] Exercise specialist asked the participants to tryout the dumbbells prepare as either low or high exercise intensity for proper fit of the exercise intensity. Borg scale ranging from zero to ten was used to measure the rate of perceived exertion (RPE) during low and high exercise intensities.[12,15]

Motion assessment

The initial motions of the arms started from about 10 degrees away from the side of the body. After the distance was fixed and stable by the participant with the instruction of the exercise specialist, the motion assessment devices were synchronized and set to default. Motion assessment devices were prepared in pair and attached to the participants immediately after synchronizing the paired devices (CC2650 SensorTag by Texas Instruments). The devices were modified by the Imbedded System Laboratory of Inha university to specifically measure the bilateral motion of the limbs. The devices had Bluetooth that could be synchronized as a pair to compare the motions of the right and left sides.

The devices were attached to the distal radioulnar joint of either arm.[18,19] Angular accelerations (deg/s^2) were assessed every one-tenth of a second and sent to a nearby computer for a real-time recording for the y-direction. After collection of results of 15 repeated lateral raises, the initial abduction and adduction angles were chosen for the initial lateral raise, 3 lateral raises in between (every two or three trials), and last lateral raise. A total of five initial abduction angles and five initial adduction angles were selected for comparison between repeats and intensities.

Statistical Analysis

Sample size was determined based on previous studies prior to the assessment. As low as five subjects per group were used to assess kinematic difference in men and women.[20,22] The normality analysis was performed for parametric test. One-way repeated ANOVA was performed to compare between repeated trials of the initial, middle, and final repetitions. One-way ANOVA was performed to compare between the results of men and women. The results were given as means and standard error (SD). Statistical significance was accepted for the *P*-value of .05.

RESULTS

Each bout was assessed for RPE (Rated Perceived Exertion). Rate of Perceived Exertions for the low and high exercise intensities for men and women groups were 6.2 (±1.55) and 7.5 (±1.27) (P=.056), and 8.8 (±1.30) and 9.5 (±0.71) (P=.24), respectively. After for the main data, the initial abduction angles between the repetitions were compared. Significant differences were not observed between the repeated initial abduction positions for either low and high intensities for both men and women. Second, the initial adduction angles between the repetitions were compared (Table 1). Although the adduction angle for the left side did not show significant differences between the repetitions, the right side showed significantly smaller mean angle in rep 1 than in rep 2 out of the initial adduction angles for the low intensity for men. As for the high intensity for men, significant differences were observed between rep 5 and rep 1, rep 2, rep 3, and rep 4 for the left side. The high exercise intensity for men of the right side showed significantly smaller mean angle for left rep 5 than for rep 1, rep 2, rep 3, and rep 4.

As for women, significant differences were shown for the low and high exercise intensities (Table 2). Low exercise intensity for women of the left side showed significant differences between rep 1 and rep 3, rep 4, and rep 5. Significant differences were also shown between rep 2 and rep 4 for the left side of the low intensity.

Significantly smaller angle was shown for rep 1in comparison to rep 4 for the right side of the low intensity (Table 2). Significant differences were shown between rep 1 and rep 2, rep 3, rep 4, and rep 5 for the left side of the high intensity. Furthermore, significant differences were shown between rep 1 and rep 2, rep 3, rep 4, and rep 5 for the right side of the high intensity.

Finally, Table 3 compared mean differences of initial angles between men and women for each repetition. Significantly different angles were shown for rep 2 and rep 4 for the left side and rep 1, rep 2, and rep 4 for the right side. Significantly larger mean angle was shown for the left side for rep 2 in comparison to rep 5 for the high intensity bout. Significant mean differences were also shown for the right side for rep 1, rep 2 and rep 5 during high intensity bout.

DISCUSSION

Improperly conducted physical activity have been reported by various reports to lead to postural imbalance or musculoskeletal complications. Musculature and muscle strength should be identical or equal for the maintenance of the healthy musculoskeletal system. Sex differences in kinematic adaptations to muscle fatigue have previously been reported. Men and women have different responses fatigue included by repetitions in exercise.[9] For example, previous studies reported of less resistance to fatigue by women in comparison not men or greater increase in

Table 1. Changes in initial adduction positions (°) for men

Repetitions	Initial angles (°)	Rep 1 (P-values)	Rep 2 (P-values)	Rep 3 (P-values)	Rep 4 (P-values)
Intensity=1	Men adduction angles (left)				
Rep 1	99.7 ± 4.72		1.000	1.000	.489
Rep 2	95.0 ± 2.16	1.000		1.000	1.000
Rep 3	98.1 ± 3.38	1.000	1.000		.870
Rep 4	88.0 ± 5.59	.489	1.000	.870	
Rep 5	87.1 ± 3.64	.340	1.000	.623	1.000
	Men adduction angles (right)				
Rep 1	94.6 ± 3.55		.010*	1.000	.295
Rep 2	79.5 ± 1.42	.010*		.162	1.000
Rep 3	90.3 ± 2.32	1.000	.162		1.000
Rep 4	84.9 ± 4.47	.295	1.000	1.000	
Rep 5	85.8 ± 2.60	.471	1.000	1.000	1.000
Intensity=2	Men adduction angles (left)				
Rep 1	85.5 ± 4.12		1.000	1.000	.671
Rep 2	92.4 ± 3.89	1.000		1.000	1.000
Rep 3	92.3 ± 2.08	1.000	1.000		1.000
Rep 4	96.9 ± 4.07	.671	1.000	1.000	
Rep 5	131.2 ± 6.36	.000*	.000*	.000*	.000*
	Men adduction angles (right)				
Rep 1	85.7 ± 5.75		1.000	1.000	.671
Rep 2	88.7 ± 2.20	1.000		1.000	1.000
Rep 3	91.6 ± 1.94	1.000	1.000		1.000
Rep 4	91.2 ± 3.43	1.000	1.000	1.000	
Rep 5	131.3 ± 6.76	.000*	.000*	.000*	.000*

*$P<.05$, Intensity 1: low intensity (1RM<60%), Intensity 2: high intensity (1RM>80%), Rep: repetitions, Rep 1: initial repetition, Rep 3–4: every 3rd or 4th repetition, Rep 5: final repetition

Table 2. Changes in initial adduction positions (°) for women

Repetitions	Initial angles (°)	Rep 1 (P–values)	Rep 2 (P–values)	Rep 3 (P–values)	Rep 4 (P–values)
Intensity=1	Women adduction angles (left)				
Rep 1	63.4 ± 7.59		.207	.004*	.000*
Rep 2	78.1 ± 3.05	.207		1.000	.027*
Rep 3	86.6 ± 2.76	.004*	1.000		.810
Rep 4	97.5 ± 3.05	.000*	.027*	.810	
Rep 5	82.9 ± 3.05	.026*	1.000	1.000	.215
	Women adduction angles (right)				
Rep 1	69.2 ± 7.29		.513	.123	.019*
Rep 2	81.4 ± 3.17	.513		1.000	1.000
Rep 3	85.0 ± 1.22	.123	1.000		1.000
Rep 4	89.3 ± 3.06	.019*	1.000	1.000	
Rep 5	86.5 ± 4.21	.066	1.000	1.000	1.000
Intensity=2	Women adduction angle	(left)			
Rep 1	119.5 ± 4.70		.000*	.000*	.000*
Rep 2	92.1 ± 1.44	.000*		1.000	1.000
Rep 3	97.5 ± 3.03	.000*	1.000		1.000
Rep 4	95.8 ± 1.56	.000*	1.000	1.000	
Rep 5	93.3 ± 1.83	.000*	1.000	1.000	1.000
	Women adduction angle	(right)			
Rep 1	114.9 ± 3.92		.000*	.000*	.000*
Rep 2	84.2 ± 1.73	.000*		1.000	1.000
Rep 3	82.1 ± 2.97	.000*	1.000		1.000
Rep 4	89.5 ± 3.08	.000*	1.000	1.000	
Rep 5	114.9 ± 4.33	.000*	.372	.986	.021*

*$P<.05$, Intensity 1: low intensity (1RM<60%), Intensity 2: high intensity (1RM>80%), Rep: repetitions, Rep 1: initial repetition, Rep 3–4: every 3rd or 4th repetition, Rep 5: final repetition

Table 3. Comparisons of initial abduction angles between men and women for each repetition

Intensity 1	Mean diff (SE) Left side	P-values	Mean diff (SE) Right side	P-values
rep 1	−36.24 (8.94)	.000*	−25.36 (8.11)	.008*
rep 2	1.85 (3.36)	.589	−36.24 (8.94)	.001*
rep 3	−16.91 (3.68)	.017*	1.85 (3.36)	.589
rep 4	−5.24 (2.71)	.068	−16.91 (3.68)	.000*
rep 5	−11.52 (4.41)	.433	−5.24 (2.71)	.068

Intensity 2	Mean diff (SE) Left side	P-values	Mean diff (SE) Right side	P-values
rep 1	34.06 (6.23)	.000*	29.16 (7.10)	.001*
rep 2	−0.28 (4.31)	.136	34.06 (6.23)	.000*
rep 3	5.15 (3.61)	.949	−4.41 (2.84)	.136
rep 4	−1.11 (4.35)	.170	−.28 (4.31)	.949
rep 5	−37.87 (6.62)	.014*	−9.48 (3.48)	.014*

*$P<.05$, Intensity 1: low intensity (1RM<60%), Intensity 2: high intensity (1RM>80%), Rep: repetitions, Rep 1: initial repetition, Rep 3–4: every 3rd or 4th repetition, Rep 5: final repetition

shoulder movement variability with fatigue by men.[9] In order to observe the effects of fatigue by repetition and different exercise intensities, this study conducted repeated lateral raises with 10 men and 11 women. Repeated lateral raises were conducted until fatigue or more than 15 repetitions with exercise intensities of low (≤40% of 1-RM) and high (75~85% of 1-RM). The results did not show significant differences for both low and high intensities for both men and women during the initial abduction locations. However, significant differences were shown during both low and high intensities for men and women. Although similar muscle groups are involved during concentric and eccentric motions of abduction and adduction motions, respectively, different acute physiological responses can be observed. That is neuromuscular, metabolic, hormonal, and anabolic signaling responses have been reported to be prominently observed during the dominantly eccentric contraction.[21]

Adduction position results showed more significant differences during high intensity repetitions men according to Tables 1 and 2. Greater number of significant differences were shown for women as the intensity increased. Such indicate that greater motion variations occur for women especially during increased intensity. Although previous studies reported of less kinematic alterations in response to fatigue in women than men, results show variations due to different responses by the participants.[9] Although greater number of significant differences were observed by women, the angle differences between repetitions, especially during the last phases of the repetitions, were greater in men according to the results of this study. Such results are consistent with previous findings.[9,22] It was also suggested that men and women use different kinematic strategies to adapt to muscle fatigue. Men alter mean movements while women induce movement-to-movement variability.[9]

Comparison of the initial angles showed greatest variations during the initial and final repetitions. In addition, the last repetition with accumulated fatigue due to intensity and repetitions showed greatest variation in the initial positional angle. However, RPE did not show significant difference between men and women. Such indicate that alteration to movement location did alter due to fatigue, alterations to location may not have occurred due to greater sense of fatigue in women in comparison to men. Previous reports indicate less muscle fatigability by women due to different contractile mechanisms.[23] Women may alternatively response to fatigue in different manner.

CONCLUSION

In this study, men and women showed mixed kinematic changes during high intensity eccentric motion during lateral raises especially during first and last repetitions. Special attention should be considered when considering training for both men and women to avoid alteration to kinematics and related dyskinesia of the upper limbs during symmetric repetitive exercises.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests.

ACKNOWLEDGMENT

This study was funded by 2020 Namseoul University research fund.

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