THE EFFECT OF STRENGTH TRAINING NECK FLEXORS AND EXTENSORS ON THE BIOMECHANICS OF FEMALE'S FOOTBALL PLAYERS HEADING

Rumi Iqbal Doewes[1], Gunathevan Elumalai[2]*, Waluyo W[1], Vadivelan Lohonathan[3], Kumaran Gengatharan[4], I Nyoman Sudarmada[5]

[1]Faculty of Sport, Universitas Sebelas Maret, Jl. Ir. Sutami, 36A, Kentingan, Surakarta, Indonesia; [2]Faculty of Sport Science and Coaching, Universiti Pendidikan Sultan Idris, Tanjung Malim, Malaysia; [3]Department of Sports, Institut Pendidikan Guru Kampus Pendidikan Teknik, Indonesia; [4]Institut Pendidikan Guru Sultan Abdul Halim, Sungai Petani, Kedah, Malaysia; [5]Department of Sports, Universitas pendidikan Ganesha, Indonesia

Abstract

The research purpose was determined the effect of strength training neck flexors and extensors on the biomechanics of female football players heading. This is an experimental research with one group pretest-posttest design. The research participants are 3 female football players in midfield position. During the treatment, the samples underwent strength training neck flexors and extensors consisting of 3 exercises namely head-ball-head isometrics, partner-assisted neck resistance, and neck machine flexion and extension for 8 weeks (3 sessions per week). Data collection was carried out by testing of standing headers, jumping headers, and running headers. Data analysis was performed by paired t-test with the help of SPSS 16. The results showed that there was no significant effect of strength training neck flexors and extensors on the biomechanics of female football players heading with tcounts of all heading biomechanics variables in the standing, jumping and running tests < 4.303. Heading biomechanics, related to the angular acceleration of the head, the results of the heading motion analysis show that the highest angular head acceleration is produced in the running header test with a mean difference of 0.175 rad/s2 for running headers, 0.044 rad/s2 for jumping headers, and 0.004 rad/s2 for standing headers. With a running approach when heading, running generates a large force to jump, then when the body on top of the jump, forms a greater angle of hip and knee extension to transfer the force to the ball. As the head approaches the ball, the hips lean back at a greater angle then the trunk forwards at a smaller angle. Then the movement is fixed by less neck extension and greater neck flexion.

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*Corresponding Author: Gunathevan Elumalai, Faculty of Sport Science and Coaching, Universiti Pendidikan Sultan Idris, Tanjung Malim, Malaysia

Correo-e: gunathevan@fsskj.upsi.edu.my

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INTRODUCTION

Wahlquist and Kaminski (2020) explain that one of the most popular sports in the world is football. This is because there are 260 million players and even more than this, playing football as both professional and amateur players. In addition to having many players, football is also a contact sport and is the only sport that uses the head intentionally and unprotected to advance and control the ball, in which this action is called heading technique (Erkmen, 2009). Heading skills are taught after players learn and practice the basics of dribbling, passing and shooting. Heading is a skill that cannot be separated from the game of football, every player at all levels needs to master this skill in both training and competition conditions.

Headings are considered an offensive or defensive move where players can utilize these skills for actions such as deflecting the ball from their goal when it comes from a corner taken by the opponent, passing to a teammate, scoring from a corner or long passes as long as the ball is from the air. The same for using heading actions, Sarajärvi et al (2020) describe in their analysis of 920 headings in the 2017–2018 English Premier League season that the most headings were made to cause loss of the ball such as preventing the opponent's spatial progress when using direct attacks with long passes, whereas as regards their execution, headings were made during set play during throw-ins and goal kicks.

Football is a unique sport with rules prohibiting the use of the upper extremities, except for throw-ins or players in the goalkeeper position. Analysis of goals scored in the 2012 European Championship match shows that heading is in second place as the act of scoring goals (27.6%) because most goals are scored by shooting (40.8%) and the third is using the inside of the foot (21.1%) (Michailidis et al., 2013). In addition, the execution of heading depends on a number of different conditions such as intentional heading of 80%, heading duels of 12%, and 3% of being hit (Beaudouin et al., 2020).

Heading is a difficult and complex task because it has to be done with other activities such as running, jumping or standing. Therefore special training is needed to master and execute the correct heading. The correct heading is done by striking the ball using the head, not the other way around, namely hitting the head using the incoming ball. When striking the ball, contact occurs using the frontal bone of the skull and the neck muscles need to be strengthened, this aims to minimize the resulting head acceleration (Erkmen, 2009). When heading, the player must be prepared for the impact that will be faced by strengthening the neck muscles, so that the heading is carried out in one movement by moving the whole body. This is done to reduce injuries during heading, because heading events occur on average 6-12 times per game with high ball speeds (Rodrigues et al., 2016). Therefore, neck exercises are needed to strengthen the neck muscles.

Peek et al (2022) found that, on average, players who completed neck exercises showed an increase in isometric neck strength and a decrease in head impact during heading. Higher neck strength is associated with lower head acceleration during intentional heading in football (Peek et al., 2020). This is because greater head acceleration is associated with head injuries and understanding exercises for the flexors and extensors of the neck helps to stabilize and reduce head acceleration during impact thereby helping to prevent head injuries. Becker et al (2019) explained that the flexors and extensors of the neck must specifically ensure the coupling of the trunk and head when in contact with the ball, so that the physical mass of hitting the ball increases and the acceleration of the head decreases. According to this, stronger neck flexors and extensors will provide a better connection of the anatomical structures and make the ball heading in football safer. So that strength training, especially flexors and extensors of neck movements can be applied. Dezman et al (2013) demonstrated that strength training of the flexors and extensors of the neck reduces the head acceleration experienced during low-velocity heading in experienced collegiate players.

As previously explained, heading can be done by running, jumping or standing, so this skill requires good coordination. Proper leg movement and vertical jump height are key points that affect the development of good inter- and intramuscular coordination (Sarajärvi et al (2020). In this case, biomechanical analysis is needed to explain good heading performance in standing, running and jumping conditions. Therefore, this study aims to find out whether there is effect of strength training neck flexors and extensors on the biomechanics heading of female football player in heading tests conducted in three conditions (standing, jumping and running).

Literature review

Football heading biomechanics

Heading is a basic technical skill in the football using the head. The use of headings in football games, such as, pass the ball to a friend to put the ball in the direction of the opponent's goal and break the opponent's attack. Heading is done by contacting the ball near the hairline or forehand with an active movement of the head, so it can be likened to not letting the ball hit the head but the head that should have hit the ball. In theory, in doing heading begins with hyperextension of the body followed by movement of the chin towards the chest. The greater the body extension, the greater the body's speed to advance towards the ball. Then when contact with the ball, balance is needed with arms extended forward. In addition to maintaining balance, the position of the arms that are stretched also aims to protect players when heading from other players. When it involves a jump while heading, the legs are slightly extended and the knees are bent, the goal is to prepare to strike the ball.

Heading biomechanics includes considerations related to linear acceleration and head rotation (Wahlquist and Kaminski, 2020). Hips are bent to bring the trunk and head toward the ball. The arms are pulled back and the head and neck are fixed by the flexors and extensors of the neck so that the head is set as a firm surface for contact. If the ball is contacted on the top of a jump, when the vertical velocity is zero, the trunk must bend to exert a force on the ball. Failure to isometrically contract the neck muscles on contact can result in the head being accelerated backwards which reduces the amount of control the player on the ball and forces some linear head acceleration.

Strength training neck flexors and extensors

Strength training is a key component to success in many sports and physical activities. The purpose was developed a solid foundation of strength by focusing on improving one's muscular frame through progressive loading by exerting maximal force against the resistance of an applied load. In any physical activity, muscles grow in response to loads placed on them. Over time, the muscles adapt to these stimuli and require additional loads. Many athletes do strength training to improve sports performance and reduce the risk of injury but many others are primarily concerned with lifting to be more lifted and/or become a stronger human being. With regard to physical appearance, no part of the human body is seen more than the face and neck. Head movement occurs through movement in the cervical spine, the muscles that act on the cervical spine play an important role in stabilizing the head and neck which contains the brain and spinal cord which consists of the central nervous system.

Kirkendall (2011) explains that in football heading, the neck muscles have important role. The cervical spine comprises the skeletal structures of the neck, and the joints formed between the seven vertebrae allow neck movement to occur in all three planes of motion. Neck movements can be in the form of flexion and extension, namely moving the chin down and up, or lateral flexion and rotation, namely tilting the head to one shoulder or turning the head. The sternocleidomastoid muscle is the main muscle that plays a role in neck flexor, while the splenius capitis muscle is the main muscle that plays a role in neck extensor. As for the lateral flexion movement, contract the two muscles to the left or right to move the head. The main factor in the neck moves is that they provide the information to be able to target most of the neck muscles using just two exercises. Combinations of two movements such as neck extension and neck flexion will work any target muscle by doing one exercise for each of the movements. Consequently, a superset of neck extension and neck flexion exercises together can be an efficient strategy for developing all parts of the neck in a short of time.

Methods

Research design

The research was used experimental method. The application of this method was based on the fact that research was carried out by giving treatment to subjects and then tests are carried out after the subjects undergo treatment to determine the effect of the treatment. The research design used "one group pretest-posttest design". Gall et al (2014), explained that this design can be used as an exploratory experiment, especially if the researcher can predict the expected pretest-posttest changes in research participants if they do not receive experimental intervention.

Participant (Subject) characteristics

The research subjects were 3 female football players. The inclusion criteria for research subjects were 18-22 years old, players in a midfielder position.

Sampling procedures

The sampling technique used saturated sampling. Saturated sampling is a sampling technique when the entire population is sampled (Sin, Nopianto, & Fardi., 2020).

Experimental manipulation or interventions

This study used a one-group pretest-posttest design, therefore there was only one group, namely the experimental group where participants underwent strength training neck flexors and extensors. Participants underwent the intervention for 8 weeks with 3 sessions/meetings per week (Sermaxhaj, et al., 2021), namely on Monday, Wednesday and Friday. So that the total sessions/meetings are 24 sessions/meetings. Strength training for neck flexors and extensors is performed with neck machine flexion and extension, partner-assisted neck resistance, and head-ball-head isometrics (figure 1). In the head-ball-head isometrics exercise, the concept is to provide resistance by pushing the ball between the partner's foreheads. In the partner-assisted neck resistance exercise, the concept is to provide resistance with the arms extended with the partner's palms on the forehead. The subject tries to flex the neck forward against the resistance given by the partner. In the neck flexion and extension machine exercise, the concept is trying to hold the neck position when flexed where the forehead is placed on the pad machine, the subject is trying to hold the neck when the chin is towards the chest, and to hold the neck position when the extension where the back of the head is placed on the pad machine, the subject is trying to hold the neck when lifting the chin to the ceiling. Exercise duration from 10 seconds to 25 seconds, 6-8 reps, 3-6 sets, and 15-30 seconds rest between sets **(Figure 1)**.

Data collection and research instruments

The research data is biomechanical data of football headings. Each sample had to carry out three heading variants, namely standing header positions, jumping headers, and running headers. The three heading variants are carried out on the stationary pendulum header. The ball must be headed horizontally forward as hard as possible (Becker, et al., 2019). Each heading variant was taken to be analyzed using kinovea software

Data analysis

The data analysis used the Kinovea software then presented in tables and pictures of heading movements. Data are presented as means. Heading biomechanics data for all three heading variants were normal. So to determine the difference between the pre-test and post-test in the performance of the 3 heading variants, a paired t test was performed with a significance level of 5% ($p < 0.05$). Data analysis was performed with SPSS 16.

Results and Discussion

Statistics and data analysis (Tables 1-3)

Discussion

The research purpose was determined the effect of strength training neck flexors and extensors on the biomechanics of female football players heading for 8 weeks used a heading test with standing headers, jumping headers, and running headers. Then it was hypothesized that strength training neck flexors and extensors for 8 weeks have a significant effect or difference on the biomechanics of heading before and after undergoing the training.

In contrast to the research hypothesis, after 8 weeks undergone strength training neck flexors and extensors consisting of neck machine flexion and extension, partner-assisted neck resistance, and head-ball-head isometrics, the

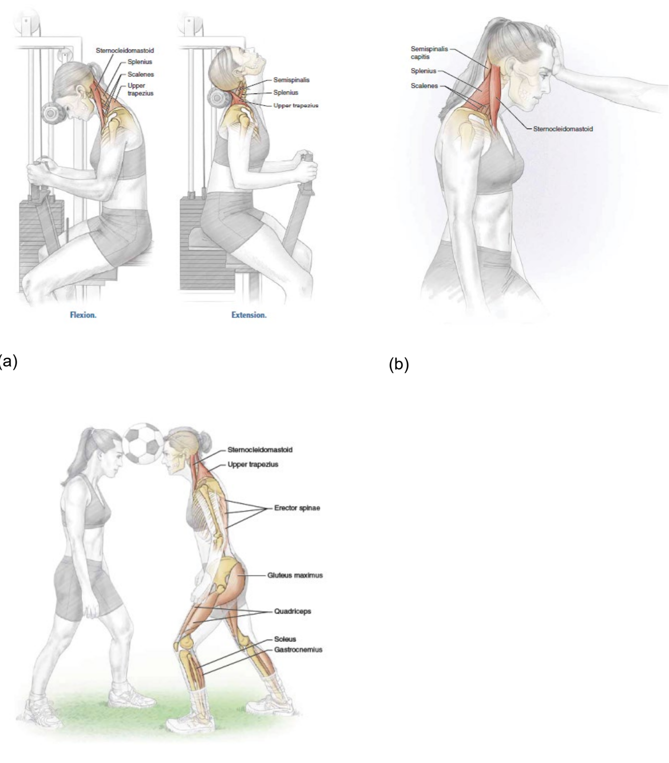

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Figure 1: Strength training neck flexors and extensors. **(a)** neck machine flexion and extension; **(b)** partner-assisted neck resistance; **(c)** head-ball-head isometrics.

Table 1: Heading movement analysis and paired t-test standing header.

No	Biomechanics Variables	Pretest (mean)	Posttest (mean)	Mean different	t-count	Sig.
1	Neck inclination angle when the body is leaning back (^{0})	10.00	10.33	0.33	.050	.965
2	Trunk angle when leaning back (^{0})	13.33	12.33	-1.00	-.866	.478
3	Hip angle when leaning back (^{0})	167.00	163.33	-3.67	-1.677	.235
4	The neck inclination angle when pushing the head forward (rad)	0.30	0.24	-0.06	-.922	.454
5	Trunk angle when pushing head forward (^{0})	11.67	5.00	-6.67	-3.050	.093
6	Hip angle when pushing head forward (^{0})	172.67	176.33	3.67	2.524	.128
7	Angular velocity of pushing the head forward (rad/s)	0.04	0.04	0.01	2.000	.184
8	Angular acceleration of pushes the head forward (rad/s^2)	0.005	0.009	0.004	3.464	.074
9	Angle of neck follow through (rad)	0.66	0.68	0.02	.225	.843

Table 2: Heading movement analysis and paired t-test of jumping header.

No	Biomechanics Variables		Pretest (mean)	Posttest (mean)	Mean different	t-count	Sig
1	Jump start stage	Shoulder angle of jump start (^{0})	17.33	25.67	8.33	2.868	.103
2		Hip flexion angle of jump start (^{0})	161.33	149.33	-12.00	-.887	.469
3		Knee flexion angle of jump start (^{0})	122.67	117.00	-5.67	-1.264	.334
4		Ankle angle of jump start (^{0})	71.33	67.33	-4.00	-.873	.475
5	Take off stage	Shoulder angle of take off (^{0})	27.33	37.67	10.33	.469	.685
6		Hip extension angle of take off (^{0})	187.33	183.33	-4.00	-.408	.723
7		Knee extension angle of take off (^{0})	168.67	163.67	-5.00	-.908	.460
8		Ankle angle of take off (^{0})	128.67	130.33	1.67	.898	.464
9		Initial speed of take off (m/s)	34.34	35.97	1.63	.499	.667
10		Acceleration of take off (m/s^2)	0.30	0.29	-0.01	-.327	.775
11		Power of take off (J/s(Watt))	522.00	522.55	0.54	.298	.794
12		Force of take off (N)	16.49	15.97	-0.52	-.301	.792
13		Kinetic energy of take off (J)	28830.92	32241.17	3410.24	.585	.618
14	Top of jump stage	Shoulder angle of top of jump (^{0})	10.00	10.67	0.67	.080	.944
15		Hip extension angle of top of jump (^{0})	173.33	175.67	2.33	.160	.888
16		Knee extension angle of top of jump (^{0})	161.00	173.67	12.67	.806	.505
17		Ankle angle of top of jump (^{0})	132.00	133.00	1.00	.077	.946
18		Vertical speed (m/s)	32.28	33.91	1.63	.498	.668
19		Acceleration of top of jump (m/s^2)	0.30	0.29	-0.01	-.312	.785
20		Maximum jump height (m)	0.29	0.27	-0.02	-1.323	.317
21	Head movement	Neck inclination angle when the body is leaning back (^{0})	8.00	6.67	-1.33	-.383	.739
22		Trunk angle when leaning back (^{0})	7.67	7.67	0.00	.000	1.000
23		Hip angle when leaning back (^{0})	190.00	169.00	-21.00	-3.085	.091
24		The angle of inclination of the neck when pushing the head forward (rad)	0.21	0.20	-0.01	-.055	.961
25		Trunk angle when pushing head forward (^{0})	9.67	7.00	-2.67	-.432	.708
26		Hip angle when pushing head forward (^{0})	167.33	160.67	-6.67	-.410	.721
27		Angular velocity of pushing the head forward (rad/s)	0.08	0.12	0.04	.704	.554
28		Angular acceleration pushes the head forward (rad/s^2)	0.031	0.076	0.044	2.844	.105
29		Angle of neck follow through (rad)	0.44	0.54	0.10	.510	.661

exercises applied did not show statistically significant differences in heading biomechanics in standing header, jumping header, and running header performance. In line with the research results, previous research also showed similar results that the benefits of a strength neck flexors and extensors training program applied for 6 weeks could not be confirmed statistically (Becker et al., 2019). According to Becker et al (2019), the hypothesis may be accepted that only players who have unfavorable anthropometric conditions or neck muscles who are fundamentally weaker will benefit from this neck strengthening program in the sense of reducing head acceleration. In addition, the heading test that is applied is a heading test with a ball that is not moving. The use of a heading test with a ball that is not moving does not give a large enough impact to both the head and the ball.

Heading biomechanics, related to the angular acceleration of the head (Wahlquist & Kaminski, 2020). Although the pretest and posttest comparison showed no significant difference, the angular acceleration of the head slightly increased in view of the mean difference. The running header test showed a larger mean difference when compared to the standing header and jumping header tests, namely 0.175 rad/s^2 for running headers, 0.044 rad/s^2 for jumping headers, and 0.004 rad/s^2 for standing headers. When viewed from the heading movement, heading is done with a bent hip to push the trunk and head towards the ball, then the head and neck are fixed by the neck flexors and extensors (Kirkendall et al., 2001). The results showed that during the running header test, when the body leaned back it formed a larger hip angle, namely $174,67^0$ hip angle of pretest and $183,33^0$ hip angle of posttest with a mean difference of +8.67, then pushed the trunk towards the ball by forming a smaller angle, namely 11^0 trunk angle of pretest and 7^0 trunk angle of posttest with a mean difference of -4.00. Then the movement is focused on the neck flexors and extensors, where the neck extensors form a smaller angle, namely 8.67^0 for pretest and 6.33^0 for posttest with a mean difference of -2.33, while the neck flexors form a larger angle of 0.16 rad for pretest and 0.23 for posttest with a mean difference of +0.14.

When compared with the standing header and jumping header tests in terms of movement, the hip angle formed when the body leans back tends to be smaller than the pretest, namely $163,33^0$ for the standing header test with a mean difference of -3.67 and 169^0 for the jumping header test with a mean difference of -21.00. Then when the trunk towards the ball was formed an angle that is also smaller than the pretest, namely 5^0 for the standing header test with a mean difference of -6.67 and 7^0 for the jumping header test with a mean

Table 3: Heading movement analysis and paired t-test of running header.

No	Biomechanics Variables		*Pretest (mean)*	*Posttest (mean)*	*Mean different*	*t-count*	*sig*
1	Running stage	Hip flexion angle at running start (⁰)	167.67	172.00	4.33	.731	.541
2		Knee flexion angle at running start (⁰)	140.00	156.33	16.33	1.848	.206
3		Ankle angle at running start (⁰)	114.33	116.33	2.00	1.309	.321
4		Power at running start (J/s(Watt))	0.01	0.01	0.00	-.157	.890
5		Force at running start (N)	0.10	0.09	-0.01	-.195	.863
6		Running distance (m)	1.86	1.84	-0.03	.000	1.000
7		Running average speed (m/s)	0.06	0.05	0.00	.000	1.000
8	Jump start stage	Shoulder angle of jump start (⁰)	14.00	9.00	-5.00	-1.321	.317
9		Hip flexion angle of jump start (⁰)	153.33	156.67	3.33	.288	.800
10		Knee flexion angle of jump start (⁰)	133.67	134.67	1.00	.087	.939
11		Ankle angle of jump start (⁰)	86.67	88.33	1.67	.188	.868
12	Take off stage	Shoulder angle of take off (⁰)	18.33	12.00	-6.33	-2.321	.146
13		Hip extension angle of take off (⁰)	187.33	191.67	4.33	.426	.712
14		Knee extension angle of take off (⁰)	164.33	166.67	2.33	.279	.807
15		Ankle angle of take off (⁰)	132.00	130.00	-2.00	-.555	.635
16		Initial speed of take off (m/s)	32.71	31.09	-1.63	-.377	.743
17		Acceleration of take off (m/s²)	0.32	0.33	0.01	.164	.885
18		Power of take off (J/s(Watt))	521.16	520.32	-0.84	-.349	.760
19		Force of take off (N)	17.29	18.09	0.80	.354	.757
20		Kinetic energy of take off (J)	26630.70	23160.44	-3470.26	-.456	.693
21	Top of jump stage	Shoulder angle of top of jump (⁰)	11.67	8.67	-3.00	-.472	.683
22		Hip extension angle of top of jump (⁰)	167.33	182.67	15.33	1.120	.379
23		Knee extension angle of top of jump (⁰)	165.67	162.33	-3.33	-.434	.707
24		Ankle angle of top of jump (⁰)	130.00	140.33	10.33	2.385	.140
25		Vertical speed (m/s)	30.65	29.02	-1.63	-.376	.743
26		Acceleration of top of jump (m/s²)	0.32	0.33	0.01	.310	.786
27		Maximum jump height (m)	0.30	0.33	0.03	1.525	.267
28	Head movement	Neck inclination angle when the body is leaning back (⁰)	8.67	6.33	-2.33	-1.151	.369
29		Trunk angle when leaning back (⁰)	9.67	7.00	-2.67	-.468	.686
30		Hip angle when leaning back (⁰)	174.67	183.33	8.67	1.038	.408
31		The angle of inclination of the neck when pushing the head forward (rad)	0.16	0.23	0.07	3.951	.058
32		Trunk angle when pushing head forward (⁰)	11.00	7.00	-4.00	-1.244	.339
33		Hip angle when pushing head forward (⁰)	160.33	162.00	1.67	.945	.444
34		Angular velocity of pushing the head forward (rad/s)	0.09	0.23	0.14	2.962	.098
35		Angular acceleration pushes the head forward (rad/s²)	0.058	0.233	0.175	2.558	.125
36		Angle of neck follow through (rad)	0.20	0.19	-0.01	-.211	.853

difference of -2.67. Then the focus of movement on the neck is carried out with an angle of neck extension of 10,33^0 for the standing header test where this angle is greater than the pretest with a mean difference of +0.33 and 6,67^0 for the jumping header test where this angle is smaller than the pretest with a mean difference of -1.33 and the neck flexion angle is smaller than the pretest, namely 0.24 rad for the standing header test with a mean difference of -0.06 and 0.20 rad for the jumping header test with a mean difference of -0. 01.

As previously explained that the biomechanics of heading is related to the angular acceleration of the head, the results of this study indicate that the running header test gives a greater angular head acceleration, this is because in running header, the angular acceleration of the head is supported by running and jumping. In a jump, as explained by Erkmen (2009), during the top of the jump, the body must bend to transfer force to the ball. The force to produce the top of jump in the running header test was greater in the posttest, which was 18.09 N with a mean difference of +0.80, then the hip and knee extension angles formed were also greater in the posttest, namely 191,67^0 for the hip extension angle and 166,67^0 for the knee extension angle, with a mean difference of +4.33 for the hip extension angle and +2.33 for the knee extension angle. With a large force it also produces a larger head angular acceleration as well, namely with a mean difference of +0.175. Whereas in the jumping header test, it actually showed the opposite, namely a smaller force and extension angle. With a small force, the resulting angle is also small, with a mean differential force of -0.52, -4.00 hip extension angle and -5.00 knee angle. So as to produce an angular acceleration of the head which is not too big the mean difference is +0.044. In the standing header test, because it does not use a jump, it shows the smallest head angular acceleration, with a mean difference of only +0.004.

In running header, the contribution of the running approach to the jump heading generates the greatest force during the jumping header. Similar to the results of this study, the greatest force for jumping was observed in the running header test when compared to the jumping header test. Bauer et al (2001) explain that a running approach can add force to the header by increasing the momentum that impacts the ball. Meanwhile, the jumping and standing forces without running shown no observable difference (Bauer et al., 2001). A similar two to three step approach before striking the ball is adopted by most players for both striking conditions; together with the low speed of the ball toss, this may have contributed to the no statistical difference observed between the standing and jumping headers. While there may be a slight increase in forward head speed during jumping headers, it is not large enough to produce a noticeable difference in force.

Conclusion

Based on the research results and the data analysis results, it can be concluded that there is no significant effect of strength training neck flexors and extensors on the biomechanics of female football players heading. Heading biomechanics, related to the angular acceleration of the head, the results of the heading motion analysis shown that the highest angular head acceleration is produced in the running header test which can be seen from the mean different which is larger when compared to the standing and jumping header tests, namely 0.175 rad/s^2 for running headers, 0.044 rad/s^2 for jumping headers, and 0.004 rad/s^2 for standing headers. In the running approach when heading, running generates a large force to jump, then when the body is on top of the jump, forms a greater angle of hip and knee extension to transfer the force to the ball. As the head approaches the ball, the hips lean back at a greater angle then the trunk forwards at a smaller angle. Then the movement is fixed by less neck extension and greater neck flexion.

The benefits after 8 weeks of undergoing strength training neck flexors and extensors consisting of neck machine flexion and extension, partner-assisted neck resistance, and head-ball-head isometrics, the results cannot be confirmed statistically with no differences in the biomechanics of football headings in the standing header, jumping header and running header tests. Practice may benefit if the heading test is performed with the ball in motion, so that the impact on the head and ball can be seen. However, when viewed from the analysis of heading movement where the biomechanics of heading is related to the angular acceleration of the head, the results show that the highest angular head acceleration is produced in the running header test which can be seen from a larger mean difference when compared to the standing and jumping header tests. This study reveals the importance of running which contributes to jump headers resulting in high head angular acceleration. These results have implications for the basis of coaching and conditioning when female football players develop heading techniques.

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