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The Comparison between Major Muscle Activations during Different Phases in Softball Batting

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ABSTRACT

Muscle activation in baseball swing is a subject which has been extensively studied compared to softball swing. However, muscle activation in baseball swing should not be generalised to softball swing due to differences between these sports in terms of ball size, speed, and the angle of pitch. This study aims to identify major muscle activations during different phases in softball batting, namely loading, contact, and follow through. Ten female softball players participated in twenty trials of hitting a stationary ball. The peak normalized sEMG for all muscles during softball batting phases was analysed and recorded as the percentage of maximum voluntary contraction (% of MVC). During stance, it was found that left pectoralis major involved the highest muscle activity with 9.08% of MVC, while the right rectus abdominus involved the least muscle activity with 1.43% of MVC. During the loading phase, the right pectoralis major involved the highest muscle activity with 22.8% of MVC, while the right middle deltoid involved the least muscle activity with 7.03% of MVC. During the contact phase, the highest muscle activity was observed from the right external oblique with 23.93% of MVC, while the least muscle activity with 7.98% of MVC was observed from the right biceps femoris. During the follow through phase, left gastrocnemius involved the highest muscle activity with 18.09% of MVC, while right posterior deltoid had the least muscle activity with 4.49% of MVC. Overall, although nearly the same muscles were involved in softball and baseball swing, different activation patterns were shown by several muscle groups during softball

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swing. These findings would be useful for coaches to develop training programmes which specifically aim for the improvement in softball batting performance.

Keywords: Activation, batting, muscles, phases

INTRODUCTION

Softball batting involves highly skilled movements as the batter must decide where and when should the contact with the ball occur. It is crucial to master the skills of batting in order to master various styles of pitching, namely fastballs, breaking balls, and changeups. Several factors are taken into account in proper batting, such as bat speed and accuracy in predicting the contact point (Ae & Koike, 2011; Fortenbaugh, 2011).

A batter generates batting speed through a kinetic link, where sequential recruitment patterns of muscles occur, transferring the momentum from large musculature to smaller adjacent muscles (Milanovich & Nesbit, 2014). Prior to the impact between the bat and ball, the first movement is to shift the body weight to the back foot. This is followed by stepping, landing, and shifting the body weight to the front foot. Furthermore, multiple measurements, such as bat velocity kinematics, the kinetics of movements (Southard & Groomer, 2003), and ground reaction force (GRF) (Katsumata, 2007) were previously examined in lab to identify the mechanisms involved in softball and baseball batting performance. In addition, surface electromyography (sEMG) has been used to analyse batting. To date, only one comprehensive study investigated batting performance using sEMG. To be specific, Shaffer et al. (1993) found that a skilled baseball swing relied on a synchronised transfer of muscle activity, which started from the lower limbs to the trunk and finally to the upper limbs.

Although muscle activation in baseball was measured in this study, it could not be assumed that the same muscles were involved in softball swing as well. To illustrate this point, one of the differences between baseball and softball sport is the method of ball throwing by the pitcher, which may cause various reactions from the batter. Furthermore, both baseball and softball sports involve different forms of pitching release which influence the trajectory of the ball. Generally, baseball pitcher throws the ball over his head, and the mount that the pitcher stands on is 10.5 inches high. As a result, the ball which is thrown moves on a downward flight to the batter. Therefore, the baseball batter has to create a slight uppercut swing movement in order to get the bat on the plane of the pitch. Whereas, in softball, the mount where the pitcher stands on is not elevated. Moreover, the pitcher releases the pitch below the hip. Consequently, a ball can be released at the thigh level and end up at the sternum level, which is technically located at the top of the strike zone in softball. With the backspin force being placed on the pitched ball, the ball would move on an upward flight towards the batter. For this reason, the softball batter must create a slight downward swing in order to match the plane of the risen ball. Due to this circumstance, it was hypothesised in this study that the muscles activities performed during softball swing would vary from the ones performed in the baseball swing.

In addition, it was found in previous studies that some variations in muscle activity occurred even in similar movements in other sports. For example, contradictory findings were present in McHardy and Pollard (2005) and Lim et al. (2002)'s studies regarding muscle activities during a golf swing. Essentially, there are five phases in the golf swing, namely backswing/take away, forward swing, acceleration, early follow through, and late follow through. McHardy and Pollard (2005) found that abdominal obliques and pectoralis major were highly activated during the acceleration phase. However, Lim et al. (2002) found that only abdominal obliques were highly activated during the acceleration phase. With these being highlighted, it is important to identify the specific muscles being activated in various sports, especially those which share similar movements. These findings would contribute insights for coaches to be more specific in the training they provide for the improvement in athlete's batting performance.

This study attempts to identify the major muscle activities involved in softball swing. The knowledge regarding muscle recruitment would be useful for the improvement in the batting performance among junior players and beginners. Therefore, more empirical data are needed to gain an enhanced understanding of the muscle groups which are involved in softball swing execution.

METHODS

Surface Electromyography activities in batting were measured and evaluated. Following that, the sequence of swing movement was monitored with a high-speed video camera.

Participants

The participants consisted of 10 right-handed college female players with age of 24.90±0.74 years old, the height of 156.00±1.05cm, and weight of 52.30±1.83kg. All participants were injury-free during data collection. Moreover, they had obtained collegiate-level experience in playing softball and they also represented their university at university level tournaments.

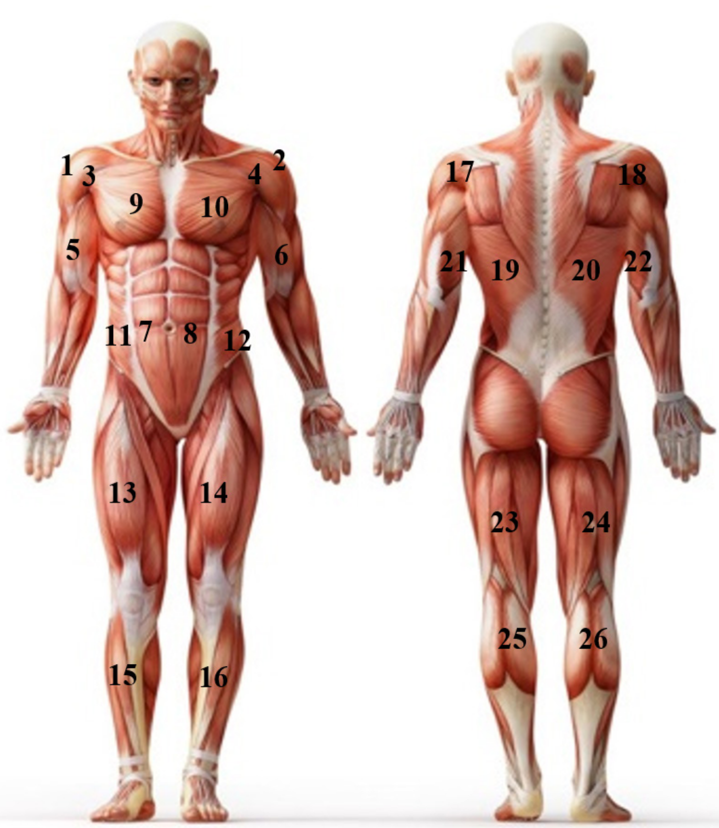
The tests were performed on two separate days. On the first day, the participants were evaluated for their ball hitting, which was done with a full swing for 20 times. They were then provided with 2 days of rest before the manual muscle test (MMT) was conducted. The participants were instructed to eat and drink normally before and during the test day. In addition, besides being instructed to avoid any strenuous exercise for 24 hours before the test, they were also instructed to sleep normally the night before the test. All of them received detailed explanations of the test procedures and risks of the research before the start. Accordingly, written informed consent was obtained from all participants. The procedures for this study had also been approved by the Ethic Committee of the Research Management Institute (RMI), Universiti Teknologi MARA, Malaysia (600-RMI [5/1/6]).

Procedure

For sEMG data recording, a wireless Myon 320 sEMG system by Myon AG was used. Due to a limited number of studies conducted on softball swing, the major muscle groups involved in the previous studies regarding baseball swing were selected for this study, as shown in Figure 1 (Vansuch, 2013). Surface electromyography electrodes were bilaterally attached to the selected muscles.

Based on Figure 1, the major muscle groups involved were pectoralis major (PM), triceps brachii (TB), biceps brachii (BB), anterior deltoid (AD), middle deltoid (MD), posterior deltoid (PD), rectus femoris (RF), biceps femoris (BF), gastrocnemius (G), latissimus dorsi (LD), external oblique (EO), rectus abdominus (RA), and tibialis anterior (TA). The protocol of electrode placement was performed according to Criswell (2010) protocol.

The areas where the electrodes would be attached to the participants' skins were firstly shaved and cleaned with an alcohol swab (McHardy & Pollard, 2005). Kendall Medi-TraceTM 530 electrode type (Ag/AgCl differential electrode) was used together with AQUA-TAC. Two electrodes were attached to a single Myon transmitter. As



No.	Muscle
1	Right Middle Deltoid
3	Right Anterior Deltoid
5	Right Biceps Brachii
7	Right Rectus Abdominus
9	Right Pectoralis Major
11	Right External Oblique
13	Right Rectus Femoris
15	Right Tibialis Anterior
17	Right Posterior Deltoid
19	Right Latissimus Dorsi
21	Right Triceps Brachii
23	Right Biceps Femoris
25	Right Gastrocnemius
2	Left Middle Deltoid
4	Left Anterior Deltoid
6	Left Biceps Brachii
8	Left Rectus Abdominus
10	Left Pectoralis Major
12	Left External Oblique
14	Left Rectus Femoris
16	Left Tibialis Anterior
18	Left Posterior Deltoid
20	Left Latissimus Dorsi
22	Left Triceps Brachii
24	Left Biceps Femoris
26	Left Gastrocnemius

Figure 1. Muscles evaluated in softball swing

a result, 32 electrodes were attached to the selected muscle groups in the participants' bodies per session. Every transmitter was also secured on the body using medical grade tape.

Prior to the recordings for warm-up and familiarisation with the test conditions, a practice session with 15 loose swings and 5 full swings was conducted. To prevent any effects of fatigue during the trials, the batter was given 10 seconds of break before the next trial. All participants used the same bat, which was 2014 BUSTOS (-10); Demarini, Hilsboro OR, USA, with a length of 0.864 metres and weight of 680 gram.

The sampling rate of the sEMG signal recording was set at 2000Hz using 20-450 Hz bandpass filter. Power frequency spectrums of the raw data were firstly identified using FFT analysis pipeline in proEMG 2.0 to observe the characteristics of the artefact noises. Furthermore, Butterworth Low-Pass (450 Hz) and High-Pass (20 Hz) filters were used before a notch filter was set at 200Hz with a steepness of 0.99. Root mean square (RMS) values of the filtered raw data were calculated in subsequent analysis. Following that, the procedures of sEMG signal recording were similar to the ones in the previous study, where wireless Myon 320 sEMG system was used to measure muscle activities (Rashid et al., 2015).

All the muscle electrical signal values of activities were recorded in percentages of the maximum neural drive. Meanwhile, a participant performed an isometric maximal voluntary contraction (MVC) of the selected muscles. Therefore, MVC data was obtained by enquiring the participants to perform maximum isometric contractions during the test.

After all the muscles were tested in sEMG recording, the MVC test was conducted on them. Before the test, each participant performed two to three submaximal contractions for all muscles tested as warm-ups. Familiarisation to the test procedure was also performed. During each MVC test, when the participants were instructed to perform these submaximal contractions with their maximum effort within a 4-second period, they were given a verbal form of motivation. Isometric contractions were performed three times for each muscle, and all muscles were tested independently after a 1-minute rest period. Moreover, manual muscle testing protocols were implemented according to Hislop and Montgomery (2009). An MVC value was determined as the highest mean of sEMG amplitude observed during the MVC task. These recording procedures were based on the sEMG recording conducted in previous studies (Fujii et al., 2009a; Fujii et al., 2009b).

Video recording was made on the batting movement on the sagittal plane (refer to Figure 2) using a high-speed camera with 240 Hz frame rate (Casio EX-ZR 800, Co., Ltd., Tokyo, Japan). The synchronisation of the video images and the sEMG signals were accomplished using an iPhone timer application (HIIT & Tabata). This application simultaneously performed recordings for both camera and electromyography reading. Furthermore, the participants were instructed to perform 20 batting trials for each session in an indoor

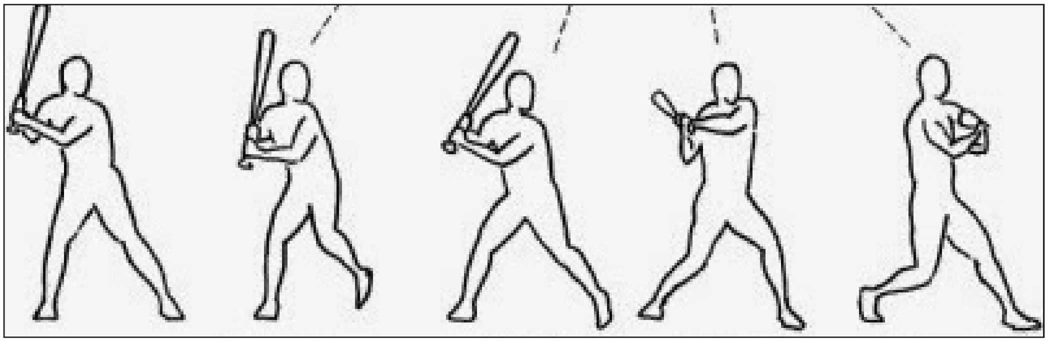


Figure 2. Sagittal plane

lab. During the trials, they had to hit a stationary ball on a batting tee. The batting tee height was adjusted to the batter's hip level, while the ball was placed on the top of the batting tee. The ball position should be adjusted to the level of the batter's navel. Essentially, this position is the normal level of a pitched ball which is within the range of batter's strike zone. Meanwhile, the strike zone is the space above the home plate which is placed between the level of the batter's armpit and above the knee (Association, 2013).

To clarify the movements of the selected muscles during batting, the movement sequences were categorised under 4 phases (refer to Figure 3):

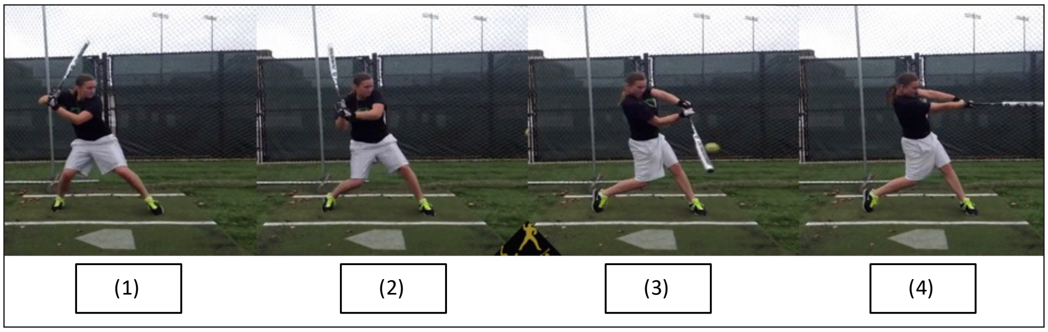


Figure 3. Phases in softball swing

The sequences of movements involved were:

(1) Stance: The phase before the shift in body weight with no specific movement.
(2) Loading (initiation of the stepping motion of the left foot): The onset time was defined by the batting movement which was video-recorded when the left foot moved off the ground.
(3) Contact (initiation of the bat swing movement until ball contact): The onset time was based on the video-recorded movement. This was specifically during the moment

when the left hand started to move down and forward until contact occurred between the ball and the bat.

(4) Follow through: The phase which began after the impact between the ball and the bat.

RESULTS

For each muscle, the maximum sEMG level (EMG_{max}) was obtained from the MVC test. This level was used to normalise the sEMG data collected during swing trials:

$$NsEMG = \frac{sEMGm}{sEMGmax}$$

$NsEMG_m$ refers to the normalised sEMG data of the muscle m, while $sEMG_m$ represents the filtered sEMG data of the muscles during the swing. The calculation of the muscle activity percentage was performed using Microsoft Excel software.

Table 1
Values of peak normalized EMG for different muscles during different phases of a softball swing

Muscles	(1) Stance	(2) Loading	(3) Contact	(4) Follow Through
Right Middle Deltoid	3.86	7.03	9.61	6.21
Left Middle Deltoid	4.80	11.37	15.41	12.24
Right Anterior Deltoid	6.52	12.69	17.81	15.07
Left Anterior Deltoid	6.44	11.41	11.62	6.27
Right Biceps Brachii	3.84	10.32	14.16	6.40
Left Biceps Brachii	3.66	13.81	20.09	13.92
Right Rectus Abdominus	1.43	8.49	16.18	9.39
Left Rectus Abdominus	2.20	9.38	17.16	9.19
Right Pectoralis Major	5.76	22.81	16.95	15.05
Left Pectoralis Major	9.08	15.64	19.51	10.56
Right External Oblique	2.58	15.20	23.93	13.97
Left External Oblique	2.17	15.21	19.01	11.74
Right Rectus Femoris	2.83	18.37	23.57	16.01
Left Rectus Femoris	2.16	18.03	13.36	10.66
Right Tibialis Anterior	1.81	12.40	16.97	14.67
Left Tibialis Anterior	1.82	14.16	19.03	15.57
Right Posterior Deltoid	2.90	7.38	10.94	4.49
Left Posterior Deltoid	3.80	13.55	10.63	9.50
Right Latissimus Dorsi	3.89	11.00	13.91	7.47
Left Latissimus Dorsi	2.46	13.06	17.22	7.60
Right Triceps Brachii	2.72	20.07	15.71	11.02
Left Triceps Brachii	2.58	12.85	11.85	7.14
Right Biceps Femoris	2.52	20.60	7.98	13.09
Left Biceps Femoris	4.31	18.18	17.55	10.83
Right Gastrocnemius	3.56	22.32	15.30	13.64
Left Gastrocnemius	5.26	20.87	19.19	18.09

Table 1 displays the peak of the normalisation of EMG muscle activation during different phases of a softball swing, which was represented in percentages. During the stance phase, Left Pectoralis Major showed the highest contraction at 9.08%, while Right Rectus Abdominus showed the lowest contraction at 1.43%. In the loading phase, Right Pectoralis Major showed the highest contraction at 22.81%, with Right Medial Deltoid showing the lowest contraction at 7.03%. During the contact phase, Right External Oblique displayed the highest contraction at 23.93%, while Right Biceps Femoris displayed the lowest contraction at 7.98%. Lastly, during the follow-through phase, Left Gastrocnemius displayed a high contraction at 18.09%, while the lowest contraction was shown by Right Posterior Deltoid at 4.49%.

DISCUSSION AND IMPLICATIONS

Baseball and softball swing is one of the most challenging skills in sports as the players need to have the contact happen between the ball and a round bat (Milanovich & Nesbit, 2014). Due to insufficient empirical data on softball swing, an analysis of softball swing movement patterns is required so that the particular muscle activities involved in the swing movement of softball players could be identified.

The selected major muscles involved in baseball and softball swing were investigated in softball batting among female softball players. Identifying the types of muscle activation during the batting motion is important to gain an understanding of the functions of these muscles throughout the batting sequence. Additionally, it was recently found that various muscle activations occurred during different phases. Overall, pectoralis major and external oblique have essential roles in assisting right-handed batters in their swings.

It was commonly hypothesised (Welch et al., 1995) that the muscles involved during softball swing would be similar to the ones involved in the baseball swing. However, this study found several differences between baseball and softball swing in terms of muscle activity patterns. The previous study by Kitzman (1964) found that the muscle activity shown by left pectoralis major ranged from moderate to very strong during the loading, contact, and follow through phases in the baseball swing. Conversely, it was found that the right pectoralis major was highly activated only during the loading phase. Meanwhile, there was a high activation of left pectoralis major during the stance phase in softball swing. Therefore, this finding suggested that there were several variations between baseball and softball in terms of the swing movements. The difference between the left and right pectoralis major activities might be due to the varied preparations done the swings done in softball and baseball. Moreover, the increase in left pectoralis major muscle activity recorded in baseball could be attributed to the distance taken by pectoralis major when the bat was brought back during the loading phase. Moreover, Kitzman (1964) mentioned that higher left pectoralis major muscle activity was recorded as the participants brought the bat farther back during the loading phase. Therefore, in softball swing, it was shown that the participants took a shorter distance when the bat was brought back. This action was comparative to the ones done in a baseball swing, specifically during the loading phase and stance phase. This was possibly due to the softball players' belief that shorter distances will provide fast batting speed compared to longer distances (Flyger et al., 2006).

This study found that external oblique showed the highest muscle activity during the contact phase in softball swing. Vansuch (2013) stated in his book that external obliques were also involved during the contact phase in the baseball swing. Furthermore, Shaffer et al. (1993) showed in their study that abdominal muscle, erector spinae, and abdominal obliques showed high muscle activity during pre-swing, swing, and follow through phases, with an MVC percentage from 60% to 100%. Higher muscle activity in the torso was possibly due to the torso rotational movement which occurred during the swing phase in softball and baseball (Chu et al., 2015). With these being highlighted, the importance of these muscles groups could be seen.

During the follow through phase, it was found that the left gastrocnemius displayed the highest muscle activity at 18.09%. On the other hand, in baseball swing, gastrocnemius muscle was listed as one of the activated muscles only during the loading phase (Vansuch, 2013). The high activation of the gastrocnemius muscle was possibly due to the softball players' main focus on maintaining their balance after contact. Lafont (2007) highlighted in his study that balance was one of the most important contributing factors to a successful softball hit and the achievement of gaze control in hitting. Furthermore, balance is essential to stop body rotation which may occur during contact with the ball. In addition, Rahman et al. (2017) found that gastrocnemius muscle had the highest activity pattern when the lower body balance was maintained. This indicated that gastrocnemius muscle played an important role in balancing. Therefore, it was also justified that the activity pattern of the gastrocnemius muscle was the highest in this study as the body balance was balanced and body rotation was stopped after contact with the ball.

It could be seen from Table 1 that there was an involvement of other muscle activities during each phase in softball swing. Although the pectoralis major showed the highest muscle activity during the contact phase, there was also a high activation of biceps femoris and rectus femoris. Additionally, both of these muscles were constantly active until the follow through phase.

Both softball and baseball battings involve a complex whole-body movement to generate power which is needed to hit a ball with spatial and temporal accuracy. This movement is based on a coordinated sequence of muscle activities to produce a fluid and reproducible swing (Welch et al., 1995). Furthermore, batters use the kinetic chain to transfer energy from the lower limb to the trunk, upper limb, bat, and the ball. When a bat, racquet, or stick is used in sports, the hitter attempts to transfer maximum energy to the ball in order to produce an impact. A previous study regarding the serves in tennis suggested that a number of body segments must be coordinated in a sequence to produce optimal racquet position, trajectory, and velocity upon impact with the ball (Fortenbaugh, 2011).

Moreover, a batter is also able to generate bat speed by utilising a kinetic link. Through this link, the sequential recruitment pattern of muscles occurs, transferring momentum from large musculature to smaller adjacent muscles (Welch et al., 1995). Stronger muscles will initiate the movement and transfer the momentum to the next activated muscles, creating an impact on the swing. Therefore, it is crucial for coaches to identify the specific muscles involved in a swing movement. Besides, specific muscles should be trained and increased in strength to produce a greater impact on the ball contact between the bat and ball.

CONCLUSION

In this study, the muscle activity of the upper and lower extremities among female players during softball batting was investigated using sEMG and a high-speed video camera. It could be concluded from the findings that several major muscle groups, such as pectoralis major, rectus femoris, biceps femoris, external oblique, triceps brachii, biceps brachii, and latissimus dorsi are essential for the execution of softball swing. It was also indicated in this study that muscle activity patterns vary between softball swing and baseball swing. Last but not least, these findings may provide notable insights to coaches and strength conditioning professionals in creating effective training programmes. These training programmes are essential for the improvement in the strength of muscles which are mainly engaged in softball swing.

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REFERENCES

Ae, K., & Koike, S. (2011, July 21). Kinetic analysis of each hand in baseball batting motion at different hitting point heights. In *ISBS-Conference Proceedings Archive* (pp. 831-832). Porto, Portugal.

Association, N. F. C. (2013). *The softball coaching Bible, Volume I.* Champaign, Illinois: Human Kinetics.

Chu, Y., Keenan, K., Allison, K., Lephart, S., & Sell, T. (2015). The positive correlation between trunk, leg, and shoulder strength and linear bat velocity at different ball locations during the baseball swing in adult baseball hitters. *Isokinetics and Exercise Science, 23*(4), 237-244.

Criswell, E. (Eds.) (2010). *Cram's introduction to surface electromyography*. Boston, USA: Jones & Bartlett Publishers.

Flyger, N., Button, C., & Rishiraj, N. (2006). The science of softball. *Sports Medicine, 36*(9), 797-816.

Fortenbaugh, D. M. (2011). *The biomechanics of the baseball swing.* (Unpublished Doctoral Thesis). University of Miami, Florida.

Fujii, S., Kudo, K., Ohtsuki, T., & Oda, S. (2009a). Tapping performance and underlying wrist muscle activity of non-drummers, drummers, and the world's fastest drummer. *Neuroscience Letters, 459*(2), 69-73.

Fujii, S., Kudo, K., Shinya, M., Ohtsuki, T., & Oda, S. (2009b). Wrist muscle activity during rapid unimanual tapping with a drumstick in drummers and nondrummers. *Motor Control, 13*(3), 237-250.

Hislop, H. J., & Montgomery, J. (2009). *Daniels and Worthingham's muscle testing: Techniques of manual examination*: *Recording for the blind & Dyslexic.* Missouri, USA: Elsevier

Katsumata, H. (2007). A functional modulation for timing a movement: A coordinative structure in baseball hitting. *Human Movement Science, 26*(1), 27-47.

Kitzman, E. W. (1964). Baseball: Electromyographic study of batting swing. *Research Quarterly. American Association for Health, Physical Education and Recreation, 35*(2), 166-178.

Lafont, D. (2007). Towards a new hitting model in tennis. *International Journal of Performance Analysis in Sport, 7*(3), 106-116.

Lim, Y.-T., Shin, I.-S., & Woo, S.-Y. (2002 March 3). Electromyographical analysis of trunk muscle activities during a golf swing. In *ISBS-Conference Proceedings Archive* (pp. 196-199). Caceres, Spain.

McHardy, A., & Pollard, H. (2005). Muscle activity during the golf swing. *British Journal of Sports Medicine, 39*(11), 799-804.

Milanovich, M., & Nesbit, S. M. (2014). A three-dimensional kinematic and kinetic study of the college-level female softball swing. *Journal of Sports Science & Medicine, 13*(1), 180.

Rahman, K., Latip, H., Mat Dzahir, M., & Azaman, A. (2017, September 6-7). Analysis of leg muscle activity on different balance training devices. In *Internation Medical Device and Technology Conference* (pp. 8-11). Johor, Malaysia.

Rashid, H., Omar, A. R., Jaafar, R., Abdullah, S. C., Ma'arof, M. I. N., Fauzi, W. M. S. W., Haron, R., Mahmud, Z., Shapie, M. A. M., & Ismail, M. A. M. (2015). Usage of wireless Myon 320 surface electromyography (sEMG) system in recording motorcyclist muscle activities on real roads: A case study. *Procedia Manufacturing, 3*, 2566-2573.

Shaffer, B., Jobe, F. W., Pink, M., & Perry, J. (1993). Baseball batting. An electromyographic study. *Clinical Orthopaedics and Related Research, 292,* 285-293.

Southard, D., & Groomer, L. (2003). Warm-up with baseball bats of varying moments of inertia: Effect on bat velocity and swing pattern. *Research Quarterly for Exercise and Sport, 74*(3), 270-276.

Vansuch, D. L. (2013). *Baseball swing mechanics*. Maryland, USA: Lippincott Williams & Wilkins.

Welch, C. M., Banks, S. A., Cook, F. F., & Draovitch, P. (1995). Hitting a baseball: A biomechanical description. *Journal of Orthopaedic & Sports Physical Therapy, 22*(5), 193-201.