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Differences in landing impulses between the traditional and swing blocking style in volleyball

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DIFFERENCES IN LANDING IMPULSES BETWEEN THE

TRADITIONAL AND SWING BLOCKING

STYLE IN VOLLEYBALL

An Abstract of a Thesis

Submitted

in Partial Fulfillment

of the Requirements for the Degree

Master of Arts

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ABSTRACT

Blocking is an important part in the game of volleyball. Previous research has shown that the swing blocking style leads to a greater jump height, penetration over the net and effective blocking area compared to the traditional blocking method. No available research has been found investigating the differences in landing. The purpose of this study was to examine the differences in landing impulses, landing time and vertical ground reaction forces (vGRF) between the traditional and swing blocking style in volleyball. Therefore, eight female collegiate volleyball players were filmed in high definition at 60Hz performing successful trials of both blocking styles. The videos were digitized and analyzed regarding the following variables: landing time, landing impulse, point of lowest COM, peak vGRF and average vGRF during the landing phase. Statistical analysis revealed that the landing impulse is bigger when subjects performed the swing blocking style compared to the traditional blocking style ($p<0.05$). All other variables showed to be similar between the two methods. These results reveal that although athletes jump higher performing the swing blocking style, their landing times do not differ. The peak vGRF was also similar between the groups, which indicates that the risk of injury due to high peak forces is alike. Having found a significant higher impulse in the swing blocking style without differences in average vGRF during the landing phase and landing time indicates that some subjects respond to greater jump height with a longer landing time and some by applying greater forces.

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CHAPTER I

INTRODUCTION

Jumping is a common and crucial aspect of many sports. In volleyball, the jumping ability plays an important role in the performance of an athlete. During jump serve, spike and block, the final height of the hands partially determines the success of an action (Salci, Kentel, Heycan, Akin, & Korkusuz, 2004). Since the rules of blocking have changed and reaching over the net is allowed, the most effective block is the one with the fastest lateral movement, the highest jump and the most penetration over the plane of the net (Farokhmanesh & McGown, 2008). Every jump of a blocking movement, however, comes with a landing, which also plays a role in performance and effectiveness in that play (Zahradnik, Jandacka, Uchytil, Farana, & Hamill, 2015).

Because effective blocking plays a crucial part to team success in volleyball (Eom & Schutz, 1992), research has been done to compare footwork patterns and blocking styles to find out the most successful way of blocking. The results show that there is an effect of blocking style on jump height, penetration of the hands over the plane of the net and the time in the air, in favor of the swing blocking style over the traditional blocking style (Ficklin, Lund, & Schipper, 2014; Neves, Johnson, William Myrer, & Seeley, 2011). The difference between these blocking styles lies in the use of the arms. In the traditional blocking style, the athlete keeps the arms neutral in front of the shoulders and in the swing blocking style the arms swing lower. A countermovement of the arms, which is used in the swing blocking style, helps to get the center of mass higher in the air (Harman, Rosenstein, Frykman, & Rosenstein, 1990; Shetty & Etnyre, 1989). This countermovement results in conclusions in favor of the swing blocking style when looking at jump height, hand penetration and time in the air (Ficklin et al., 2014; Neves et al., 2011).

Not only the jump, however, is a part of blocking. Landing always follows a jump. During landing, forces with the ground are produced, which can be as high as 6 times body weight for a volleyball spike jump (Bressel & Cronin, 2005). These high forces, together with a high frequency of jumping, may create a risk for knee injuries (Bressel & Cronin, 2005; Decker, Torry, Wyland, Sterett, & Steadman, 2003; Devita & Skelly, 1992). Several researchers have been looking at these ground impact forces and the risk of injuries, especially ACL injuries, in different landing situations. Results revealed, among other things, that more knee flexion decreases peak vertical ground reaction forces (vGRF; Zhang, Bates, & Dufek, 2000) and that unilateral landings compared to bilateral landings and women compared to men are at higher risk for ACL injuries because of higher forces, less knee flexion and more knee valgus (Pappas, Hagins, Sheikhzadeh, Nordin, & Rose, 2007; Salci et al., 2004; Young-chul, Joon-haeng, Hae-dong, & Sung-cheol, 2012).

Statement of the Problem

None of the available studies has been looking at the difference in impulse and impact forces during landing between the traditional and swing blocking style. The blocking style with the greater jump height will also create the highest impulse, according to Newton’s second law of motion. It is of interest to know if this higher impulse will be accompanied by higher vGRF values, a longer landing time or both. Not only does this influence the risk of injury, the time spent on landing also affects the ability to be ready for the following counterattack. It is important to know the advantages and disadvantages of the traditional and swing blocking style to be able to make the right decision. Until now, only advantages and disadvantages are known until the moment of greatest elevation of the center of mass. Research has to be done to look at the difference in landing impulses.

Research Questions

1. What are the differences in landing impulse between the traditional and swing blocking style?
2. What are the differences in vGRF and landing time between the traditional and swing blocking style?

Hypothesis

It is hypothesized that the greater jump height, seen in the swing blocking style, will be accompanied by a greater impulse. This greater impulse will have a greater landing time or higher vGRF.

Significance of the Study

Higher jump height in blocking seems to produce a performance advantage, since the jump height is one of the factors determining an effective block (Farokhmanesh & McGown, 2008). However, a greater jump height produces a greater impulse during landing. This greater impulse cannot only lead to injuries due to the greater forces, but it can also lead to more time spent on landing. This has implications on the performance in the next counterattack. Results of this study will provide new information about these differences between the two blocking styles and might lead to rethinking the decision volleyball players and their coaches make on which blocking style to use.

Delimitations

This study was conducted to determine the differences in landing impulses between two different blocking styles. Eight female volleyball players were videotaped from behind while executing three successful trials of each blocking style. Biomechanical markers were measured to obtain information about the landing time, the average and peak vGRF and the landing impulse.

Limitations

Limitations of this study are that data has been collected in a controlled environment. Athletes did not feel the pressure and excitement felt during competition. This might have influenced their performance on the jump as well as the landing. During competition, there is a need to land and transition quickly as long as the play is still going on (Zahradnik et al., 2015). Since there was no ball involved in this study, this pressure was not felt. Players were more familiar with the traditional blocking style, which could influence their performance and the results found. Last, all blocking movements were performed to the right side. Some athletes could have been more familiar with moving to one side over the other.

Assumptions

Assumptions made in this study are that the players would jump and execute the blocking movements as if there were a ball and an attacker at the other side of the net. It was also assumed that the trials were performed with maximal effort. Last, a five-minute practice of the swing blocking technique was expected to be enough, since the movement pattern is similar to other movements in the game of volleyball.

Definition of Terms

- Vertical ground reaction force (vGRF): We make forces with the ground in every contact with the ground. The ground reaction force is equal in size and in opposite direction with the force that we exert on the ground. It has a vertical component, which is called vertical ground reaction force.
- Impulse: an impulse is the change in momentum. The formula to calculate impulse is: $m * \Delta v = \Sigma F * \Delta t$.

CHAPTER II

REVIEW OF LITERATURE

The Volleyball Block

Blocking is an important part in the game of volleyball (Eom & Schutz, 1992). Higher ranked teams showed to be significantly more successful at blocking than lower ranked teams, which makes blocking one of the predictors of team success. A well-performed block can prevent a score from an effective spike and can also lead to a score itself. The technique that determines if a block is well-performed has greatly changed since penetration over the net is allowed (Farokhmanesh & McGown, 2008). Now the penetration over the net, the jump height and a fast lateral movement determine the effectiveness of a volleyball block. Since these characteristics of a well-performed block are available, researchers were interested in finding out the best way to perform these characteristics. Therefore, several studies have been looking at different parts of the block to find out the most effective way of performing it. The research discussed here has been focusing on the block of the middle blocker.

Footwork Patterns

The most common set given by the setter in volleyball is the one high to the outside (Farokhmanesh & McGown, 2008). It is the middle blocker’s task to move quickly along the net to find a position next to the player on the pin so they can perform a block on the outside together. To be able to carry out an effective block, the middle blocker has to reach the position at the pin on time. Therefore, a fast lateral movement from the starting position to the pin is desirable.

Several researchers compared different footwork patterns; ways of how to move quickly along the net to get to the outside. Comparisons have been made between moving sideways by executing slide steps and footwork patterns that include crossing over of the feet.

Farokmanesh and McGown (2008) only showed a difference of 0.0014s between the fastest and the slowest technique, regardless of the sex of the subjects and the direction and distance of movement. The authors concluded that the choice of footwork pattern should therefore be made on personal preference. Other researchers found different results with more conclusive outcomes (Buekers, 1991; Kwak, Jin, Hwang, & Yoon, 1989; Lobietti, Merni, & Ciaci, 2005). Kwak et al. (1989) compared the crossover step to the slide step and revealed that greater horizontal velocities are achieved with the crossover footwork pattern, in both males and females. These results are supported by the outcomes of Buekers (1991), who found greater lateral movement times when subjects used slide steps compared to crossover steps. The investigator stated that the distance travelled has an effect on the choice of footwork pattern that should be used. When a greater displacement has to be made, the crossover technique is preferred over slide steps. This is the case when a middle blocker wants to set a block at the outside. About 15 years later, Lobietti et al. (2005) revealed similar conclusions. After comparing different footwork patterns, the one including crossover of the feet showed results most desirable for the middle blocker when setting a block at the pin. The authors advised middle blockers to use or the slide crossover step or crossover step.

Of these studies only Farokmanesh and McGown (2008) found results not supporting the use of crossover steps over slide steps. All the other authors concluded that crossing over of the feet is preferred over the slide step technique when the middle blocker has to set a block at the outside (Buekers, 1991; Kwak et al., 1989; Lobietti et al., 2005).

Armswing

The swing blocking style and the traditional blocking style differ from each other in the use of an armswing. In the traditional method the arms are kept in front of the body when the player executes the footwork pattern and are lifted when the player is in the air. On the other hand, in the swing blocking style the elbows and shoulders are being extended during the lateral movement after which the arms are swung up to get the hands above the net. Thereby the swing blocking style implements an armswing. Research has been conducted to show the effects of an armswing on the vertical jumping performance.

About 30 years ago, Shetty and Etnyre were interested in the contributions of arm movements to kinematic and kinetic variables of a vertical jump (Shetty & Etnyre, 1989). The results showed that an armswing significantly improves the vertical jump height. Significant higher values for the maximum force applied to the ground, work output, power and release velocity were revealed when subjects made use of an armswing. The impact force was significantly greater when the subjects did not use their arms. The authors concluded that the beneficial effects of using an armswing might even be greater when people know how to use their arms more effectively. These results are in agreement with findings of other researchers (Harman et al., 1990; Lees, Vanrenterghem, & Clercq, 2004). Lees and his collegues (2004) found the height of the COM at takeoff as well as the maximum height of the COM to be significantly higher when subjects used an armswing. The differences were 0.024m and 0.086m respectively. The takeoff velocity was also significantly higher when the arms were used, with an increase of 8.9%.

Over time several different theories have been suggested to explain the positive effect that armswing has on vertical jump performance. One of them is the ‘transmission of force’ theory, which was first suggested by Payne, Slater and Telford (1968). This theory implies that the upward acceleration of the arms during armswing is accompanied by a downward force at the feet. However, as Harman et al. (1990) notice, this theory might be too easy to explain the whole effect, since research has shown that the arms decelerate relative to the rest of the body at the end of this motion. Another concern is that the vertical joint force at the shoulder is not exactly represented in the vertical ground reaction force (Lees et al., 2004). A second theory is the ‘joint torque augmentation’ theory: the upward accelerating arms create a downward force on the shoulders and the rest of the body with the consequence that the muscles of the lower extremity slow the velocity of their contraction down (Harman et al., 1990; Lees et al., 2004). Due to the force-velocity relationship of muscle contraction, this slower velocity enables the muscles to exert a greater force, which can result in better performance. This theory didn’t satisfy researchers, neither, which resulted in a third theory: the ‘pull’ theory (Harman et al., 1990). Harman et al. (1990) noticed that the arms decelerate relative to the rest of the body at the end of the armswing. This notion made them propose that as the arms decelerate, they pull on the rest of the body. Lees and colleagues (2004) support this theory. They state that as the arms move beyond horizontal, they pull on the trunk with a decrease of energy of the arms and an increase of energy of the rest of the body.

These results favor the swing blocking style over the traditional blocking style, since the armswing is only implied in the swing blocking style.

Countermovement

Not only an armswing, but also a countermovment is a widely implemented movement to increase jumping performance. Harman et al. (1990) broadened the results of their study by taking the countermovement in addition to the armswing into account. A countermovement is defined as a quick bend of the knees in which the COM is lowered before the COM is lifted upwards. Harman et al. wanted to get to know the interaction between the countermovement and the arm swing. They let their subjects perform four different kinds of jumps: with countermovement and arm swing, with countermovement but without armswing, without countermovement but with armswing and without both countermovement and armswing. The results revealed that using an armswing significantly increased pre-takeoff COM rise, post-takeoff COM rise, peak vGRF, peak positive COM velocity and total jump height. Jumps with a countermovement had a significantly higher post takeoff COM rise, peak positive COM velocity and total jump height than jumps without a countermovement. However, subjects took 71-76% more time until takeoff when they implemented a countermovement compared to jumping without countermovement, which could be a reason not to implement this motion. These results support the plenty available research showing a significant effect on jump height when implementing a countermovement compared to a squat jump (Amasay, 2008;

Bobbert, Gerritsen, Litjens, & Van Soest, 1996). Amasay (2008) found the jump height to be significantly higher when subjects started in an upright position and executed a countermovement compared to when starting in a squat position.

The explanation for an improved performance when implementing a countermovement is found in the stretch-shortening cycle. During the countermovement, the knees and hips are flexed. This flexion causes lengthening of the muscles (the stretch part of the stretch-shortening cycle) and storage of absorbed energy in series elastic components (Bobbert et al., 1996; Harman et al., 1990; LeVeau, 2011). This stored energy results in the lengthened muscle being able to produce more energy then muscle of normal length during concentric muscle action. During the concentric muscle action of a jump this energy is released which causes a greater force and improved performance. The lengthening of the muscle does not only have an effect on series elastic components, but it additionally influences the nervous stimulation of the muscle (Bobbert et al., 1996). Stretching a muscle increases stimulation of muscle spindles, which in turn activate spinal reflexes that increase the level of muscle stimulation. Bobbert and his colleagues (1996) indicate though, that it is hard to see if this increased nervous stimulation has indeed an effect in the countermovement, but they state that it cannot be ruled out that it does play a role.

After knowing that performing a countermovement does increase vertical jumping performance (Amasay, 2008; Bobbert et al., 1996; Harman et al., 1990), the question arises how much difference in countermovement there is between the two blocking styles. Although the difference in implementation of a countermovement between the blocking styles is not as obvious as the differences in the use of the arms between the two styles, it can be assumed that the countermovement will be greater in the swing blocking style due to the implied armswing, which is only part of the swing blocking style. If this is indeed the case, both the countermovement and the armswing favor the swing blocking style over the traditional blocking style when looking at vertical jump performance.

Blocking Styles

After gaining information about the effectiveness of the use of an amswing and a countermovement regarding vertical jump height performance, it is of importance to know how these factors implemented in the blocking movement of volleyball players influence their blocking performance. Different blocking styles distinguish from each other in especially the use of the arms to propel the body into the air.

Neves, Johnson, Myrer and Seeley compared three blocking styles: the traditional, the chicken wing and the swing blocking technique (Neves et al., 2011). In the traditional blocking style, the arms are held neutral in front of the body. In the chicken wing blocking technique, the shoulders extend, but the elboys keep being flexed. A whole armswing with extension in shoulder and elbows is used in the swing blocking style. They wanted to find out which technique leads to the fastest lateral movement, the shortest time to get the hands above the net, the highest vertical jump and the greatest penetration over the plane of the net. For all the trials the same footwork pattern was used. The results showed that the time to get off the ground, which was used as a measurement for time spent on lateral movement, did not significantly differ between the three techniques. With the chicken wing technique the players spent the shortest time to get off the gound. They were 0.6s faster than when using the slowest way, the traditional blocking technique. Although this difference was not statistically siginificant, the authors stated that it might, however, be practically significant, since the time it takes for an offensive player to swing the arm and hit the ball is only 0.5s. The time to get the hands above the net was significantly shorter when using the chicken wing or swing blocking technique compared to the traditional blocking technique. This was in contrast with the hypothesis of the study, that stated that the traditional way would be the quickest in getting the hands above the net. Jump height and penetration over the plane of the net significantly differed between all of the groups. The swing blocking style caused the greatest jump height and net penetration, significantly higher than when using one of the two other techniques. Besides, the chicken wing blocking style created a significantly greater jump height and net penetration than the traditional blocking style. These two distinctions relate to each other. The higher the jump height, the better the precondition to penetrate the net. A factor that might have influenced the results of this study was that the swing blocking style was preferred by the coaches of the players. Although the players had two weeks time to practice the other styles, they were more familiar with the swing blocking style. Another limitation is the inclusion of defensive specialists in the study, since these players usually don’t block and are therefore not used to the movement.

Ficklin, Lund and Schipper conducted reseach to find out further further differences between the blocking styles (2014). Therefore, they compared the traditional blocking style to the swing blocking style on several variables (Ficklin et al., 2014). Like Neves et al. (2011), they looked at jump height, time spent on the approach and penetration over the net. New variables studied in this research were the vertical and horitzontal velocities of the center of mass (COM) at takeoff, the time of the block and the effective coverage of the block, which was calculated from the time of the block and the area covered by the hands. Results revealed significantly greater takeoff velocities, in both the x and y direction, elevation of the COM, time of the block and net penetration for the swing blocking technique. Also, the coverage of the block was greater for this technique and the time spent on the approach was significantly shorter than when using the traditional blocking style. The significant differene in time spent on the approach between the two techniques found in this study disagrees with the results found by Neves et al, who did not find a signficant difference between the groups. An explanation for this could be a discrepancy in definition between the two studies. All of these results found by Ficklin and his collegues (2014) favor the swing blocking style over the traditional blocking style. However, as the authors notice, factors like the ability to adjust to the opponent’s attack also play an important role. A player, who uses the swing blocking style, starts takeoff earlier and spends more time in the air, which means that, besides hand positioning, it is too late for making adjustments. The greater horizontal velocity at takeoff also causes more ‘floating.’ These factors lead to a greater chance of mistiming in the swing blocking style and are therefore factors that favor the traditional blocking style. They conclude that individual characteristics and the type of attack decide what blocking technique should be used.

Both Neves et al. (2011) and Ficklin et al. (2014) showed that the swing blocking style generated a significantly greater jump height. They proposed that this advantage is the result of the use of an armswing, which also creates a countermovement. The penetration over the net also showed to be greater when using the arms. Ficklin et al. additionally found x and y velocities, time of the block and blocking coverage in favor of the swing blocking style. All these findings show the swing blocking style to create a block with more characteristics of an effective volleyball block. The only variable that these two studies did not find the same effect on was the time spent on the approach. Neves et al. did not find a significant difference and Ficklin et al. found the swing blocking style to be the fastest. However, Neves et al. also found the swing blocking style to be fastest when comparing times to get the hands above the net between the blocking styles. All in all there was no significant result that favored the traditional blocking style over the swing blocking style. The greater jump height, penetration over the net, blocking time and blocking coverage achieved when using the arms during the approach leads to the conclusion that the swing blocking style should be implemented and used by volleyball players who haven't done that, yet. The concern that might coaches make the decision to use the traditional blocking style are greater horizontal velocities and earlier takeoff when performing the swing blocking method, which lead to a greater horizontal floating distance in the swing blocking style and less time to make adjustments.

Landing

As stated above, a lot of research has been done on the volleyball block. Researchers have been looking at different footwork patterns (Buekers, 1991; Farokhmanesh & McGown, 2008; Kwak et al., 1989; Lobietti et al., 2005), the use of the arms and a countermovement (Harman et al., 1990; Lees et al., 2004; Shetty & Etnyre,

1989) and the traditional and swing blocking style have been directly compared regarding several different factors (Ficklin et al., 2014; Neves et al., 2011). None of these factors, however, dealed with the descending part of a jump. In this part research will be discussed that focused on landing, some of which specifically on landing of volleyball players. Information about landing is important, since it can not only be a cause of injury (Decker et al., 2003; Pappas et al., 2007; Salci et al., 2004; Tillman, Hass, Brunt, & Bennett, 2004), but it also plays a role in the performance of the athlete in that play (McNitt-Gray, 2001; Zahradnik et al., 2015). Research done on landing has focused on the effect of landing height, joint stiffness, sex differences and amount of support on kinetic and biomechanical factors of landing.

Landing Height

In the 1990's, various researchers were interested in the effect of different landing heights on variables such as the impact force and adjustments in landing strategies. Dufek and Bates (1990) were two of them, who, among other things, wanted to find out the effect of height on impact forces during landing. Their interest came from the fact that these forces must be absorbed by the musculoskeletal system. Subjects landed from three different heights (40cm, 60cm and 100cm) with one foot on a force platform. The results revealed that landing height has both a significant main effect on the first peak of vGRF (caused by the toe touching the ground) and the second peak of vGRF (caused by the heel touching the ground), with higher heights causing greater forces. Regression results showed that landing height is the only variable predicting both of these forces in the subjects of their study.

McNitt-Gray (1991) broadened these results by not only looking at the effect of height on vGRF, but also investigating the effect on joint kinematics. One of the goals was to examine adjustments in landing strategies in response to different impact velocities. Greater landing heights cause greater impact velocities and therefore subjects landed from three different heights (32cm, 72cm and 128cm). With increase in landing height, the peak vGRF significantly increased, supporting the results found earlier by Dufek and Bates (1990). Similar results are found by other researchers (Young-chul et al., 2012; Zhang et al., 2000). Other results found by McNitt-Gray (1991) showed that the landing phase duration (the time between the drop and the minimum vertical position of the COM) increased in recreational athletes when the height increased. In contrast, in gymnasts the landing time decreased under these circumstances. Furthermore, McNitt-Gray (1991) found that across the different impact velocities, the COM position at contact did not differ, whereas the landing strategy did change. With higher heights the subjects went through a greater range of motion. In other words, the angular positions of the hip, knee and ankle at ground contact were the same among different landing heights, but the joint excursions were greater when impact velocity increased. Zhang et al. (2000) found similar results regarding the ROM. Subjects landing from higher heights went through greater joint excursions. They did not give results regarding the joint angle at ground contact, so no comparisons can be made pertaining this variable. Different results were found by Young-Chul et al. (2012). The researchers stated that knee flexion was greater when participants landed from bigger heights during the whole landing phase.

However, they didn’t define landing phase, so it remains unclear how exactly to compare their results to the outcomes found by other researchers.

Researchers have also been looking at the differences in energy absorption of lower extremity joints for different landing heights (Zhang et al., 2000). The peak joint moments and minimum joint powers (maximal energy absorption) for hip, ankle and knee during ground contact increased significantly with higher heights. These peaks represent maximum efforts by the muscle groups in energy absorption and occur approximately at the times of toe and heel contact. The total work done by hip, knee and ankle joints increased significantly with higher heights. When the authors compared relative work done by each of these joints and compared it in the different height conditions, no significant differences were found. This indicates that although the joints perform more absolute work when landing height is increased, the relative work performed by each joint stays the same.

All the researchers came to the same conclusions when looking at the changes in vGRF among different landing heights: the peak vGRF increases when landing height increases (Dufek & Bates, 1990; McNitt-Gray, 1991; Young-chul et al., 2012; Zhang et al., 2000). McNitt-Gray also found the ROM of the lower extremity joints to increase under these circumstances, which was in accordance with the findings of Zhang and his collegues (2000). Zhang et al. (2000) revealed moreover, that the relative work done by lower extremity joints stays the same among different landing heights.

Joint Stiffness

Besides the effect of landing height, various studies have investigated the effect joint stiffness has on landing. GRF can be has high as 14.4 times bodyweight (Zhang et al., 2000) and in the past curiosity raised how different landing strategies with effects on joint stiffness these forces and joint kinematics and energetics.

The notion that the GRF caused by the ground as a result of landing is higher in a stiff than in a soft landing is frequently proved and widely distributed (Bressel & Cronin, 2005; Derrick, 2004; Devita & Skelly, 1992; Dufek & Bates, 1990; McNitt-Gray, 2001; Zhang et al., 2000). This is the reason why knee flexion is promoted if less musculoskeletal loading is desirable. High vGRF are thought to be a risk factor for injuries (Bressel & Cronin, 2005; Norcross et al., 2013; Norcross, Blackburn, Goerger, & Padua, 2010; Young-chul et al., 2012; Zahradnik et al., 2015) and as a result decreasing these forces by performing a softer landing by using more knee flexion is a way to reduce the risk of injury.

Researchers have moreover examined effects of increased joint stiffness on joint kinematics and energetics. Devita and Skelly (1992) defined a soft landing as a landing with a maximum knee flexion angle of more than 90 degrees and they compared this to a stiff landing, one with less than 90 degrees maximal knee flexion. Both types of landings were performed of a box with a height of 59cm. When performing stiff landings, subjects showed to be stiffer in hips and knees at initial ground contact and the point of maximal knee flexion was reached earlier (after 152ms, compared to 342ms after a soft landing). This indicates that participants flexed the joints before touching the ground in preparation of a soft landing. The researchers also compared joint moments in the descent phase (last 100ms before ground contact) and the impact phase (from ground contact until vGRF reached a stable value). In the descent phase, a hip flexor moment was followed by a hip extensor moment, which was greater in the stiff landings. The role of the hip extensor moment was to slow down the hip flexion velocity. In the stiff landings, this greater hip extensor moment caused the more erect body position at impact. The knee flexion moment in the descent phase was also greater for the stiff landing than the soft landing. The authors reasoned that this might be a result of the increased hip extensor moment with the function to ensure that the knee will touch the ground flexed and not getting into hyperextension. The average impact phase lasted 126ms and 113ms in the soft respectively the stiff landing. The researchers found that the impact phase was initiated by hip flexor, which caused a forward and downward acceleration of the trunk, and knee extensor moment. After this initial phase, there was an extensor moment at each joint. Devita and Skelly did not find significant differences in the magnitude of the hip and knee extensor moments during the impact phase. The ankle plantar flexion moment showed to be higher in the stiff than in the soft landing. Another study found different results (Zhang et al., 2000). Zhang and his colleagues (2000) revealed higher moments across the lower extremity joints with increased stiffness. The set-up of their study also differed from the methods of Devita and Skelly (1992). They defined the soft, normal and stiff conditions for each subject after obtaining a mean knee flexion value at a first day of testing for each condition. However, when comparing other results of both studies, they revealed similar outcomes. The eccentric work performed by the hip and knee muscles decreased with higher stiffness, whereas the work done by the ankles increased with higher stiffness (Devita & Skelly, 1992; Zhang et al., 2000). Zhang et al. (2000) see this effect as a shift from distal to proximal parts in higher mechanical demand.

When taking a look at Newton's second law of motion, one could infer that a decreased vGRF by decreased joint stiffness will cause less acceleration. This conclusion can not be made that easily though (Derrick, 2004). Although it is right that the body's COM will undergo less acceleration in conditions of smaller forces, one has to be careful with making inferences about individual body parts. Derrick (2004) explains this by using the term 'effective mass.' The body consists of several segments and for knowing the acceleration of body parts the effective mass has to be used, which differs from the body mass when joint stiffness is not implied.

As a conclusion, the most important and widely distributed finding when comparing effects of joint stiffness on landing is the decreased vGRF with more joint flexion (Bressel & Cronin, 2005; Derrick, 2004; Devita & Skelly, 1992; Dufek & Bates, 1990; McNitt-Gray, 2001; Zhang et al., 2000). As explained above, the kinetics and energetics of the lower extremity joints also change with changing stiffness, with more work performed by proximal joints when increasing the mechanical load by less joint flexion in the lower extremity (Devita & Skelly, 1992; Zhang et al., 2000).

Base of Support

Another variable that can influence the landing kinetics and kinematics is the fact if a subject lands on one or two feet. Most of the studies done regarding this aspect have been focusing on the risk of ACL-injury. When landing unilaterally, there is less support which creates a higher demand on the landing limb (Young-chul et al., 2012). ACL-injuries are more common to happen during unilateral landings (Pappas et al., 2007). Therefore, researchers were interested in finding out differences between unilateral and bilateral landings.

A common finding when comparing unilateral to bilateral landings is that knee flexion angles, both at initial contact and at peak knee flexion, are greater when landing on two feet (Pappas et al., 2007; Young-chul et al., 2012). Pappas and his colleagues (2007) suggested as a reason that with less knee flexion the moment arm is decreased and the muscle is kept closer to resting length. Therefore the muscle can absorb energy more effectively. The researchers also found the hip abduction and knee valgus at 40 degrees of knee flexion to be greater in unilateral circumstances. The greater knee valgus angle found in unilateral landings was in accordance with their hypothesis, since both knee valgus angle (Hewett et al., 2005) and unilateral landings (Pappas et al., 2007) were associated with an increased ACL-risk. However, the greater hip abduction seen in the unilateral landing was surprising. The authors suggest that this greater hip abduction allows the hip to go through a greater range of motion towards adduction during landing and keeping the gluteus medius closer to it’s resting length with the consequence that the muscle can absorb energy more effectively.

When comparing the risk of ACL-injury between circumstances with different base of support it is of great interest to know how these affect the vGRF. Inconsistent results have been found regarding the effect of unilateral and bilateral landings on the magnitude of the vGRF (Pappas et al., 2007; Young-chul et al., 2012). Pappas and his colleagues (2007) did not find a significant effect of the type of landing on the vGRF, whereas Young-Chul and his peers (2012) revealed the vGRF to be significantly higher when subjects landed on one compared to two feet. The results found by Young-Chul et al. (2012) are more in accordance with the findings stated earlier, that unilateral landings go with less knee flexion, which causes greater vGRF (Devita & Skelly, 1992; Zhang et al., 2000).

All in all, research conducted to find out differences between unilateral and bilateral landings revealed that a smaller knee flexion angle and a greater knee valgus angle are seen in unilateral landings (Pappas et al., 2007; Young-chul et al., 2012). Although the results regarding the effect on vGRF are not conclusive between different studies, it appears reasonable to assume that unilateral landings cause greater vGRF (Young-chul et al., 2012).

Sex Effects

It is not a new finding that kinetic and kinematic variables differ among subjects with different sex. For landings biomechanical differences between the sexes have also been revealed (Decker et al., 2003; Pappas et al., 2007; Salci et al., 2004).

One of the findings was that women revealed to have a greater knee valgus angle than men during landing (Norcross et al., 2013; Pappas et al., 2007). The authors notice that this finding fits in with the higher risk of ACL-injury that women have and the increased risk of ACL-injury associated with a greater valgus angle (Hewett et al., 2005). Moreover, two studies showed that women also have increased vGRF-values during landing compared to men (Pappas et al., 2007; Salci et al., 2004), which is also associated with an increased risk of ACL-injury (Hewett et al., 2005). Decker et al. (2003) did not support this finding; their results didn't reveal a difference between vGRF between the sexes. This result was surprising to the authors; they did expect to find a difference there.

Besides similar vGRF between the sexes, Decker and colleagues (2003) also found the landing times and maximum knee flexion angle to be similar between men and women. This last finding was largely supported by a study conducted by Salci et al. (2004), who found the maximum knee flexion angle only to be significantly higher in males in one of their four landing situations. The maximum hip flexion angles also showed to be similar between the sexes most of the time (Salci et al., 2004). Similar results were found pertaining peak joint moments. Decker et al. (2003) found the peak joint moments in the lower extremity joints to be similar between the sexes, whereas the results of Salci et al. (2004) supported these findings most of the time. They revealed the knee extensor moment in women to be greater than in men, but only in one of the four conditions. The hip and ankle, as well as the knee moments in all other conditions resembled.

Although the maximum knee flexion angles are largely similar between men and women (Decker et al., 2003; Salci et al., 2004), women have greater knee extension and ankle plantar-flexion compared to men at touchdown (Decker et al., 2003). Therefore, their ankle as well as knee ROM and the angular velocities of the hip, knee and ankle are greater among women, since landing phase times are equal (Decker et al., 2003).

Summarizing, research exhibited that women have greater knee valgus and probably also greater vGRF than men during landing (Norcross et al., 2010; Pappas et al., 2007; Salci et al., 2004). Largely similar between the sexes are maximum knee flexion angles, maximum hip flexion angles and peak joint moments across the lower extremity joints (Decker et al., 2003; Salci et al., 2004). Women go through a greater knee and ankle range of motion during landing, while spending the same amount of time on landing than men (Decker et al., 2003).

Landing in Volleyball

In the previous parts, research conducted on landing has been discussed. It can be noticed that most of the researchers focused on the peak vGRF rather than the impulse over time that it creates. The most obvious reason for that is that it is the peak vGRF that can be a cause of injury, not the impulse (Hewett et al., 2005). Also, only two studies included landing time in their analysis (Decker et al., 2003; McNitt-Gray, 1991). Decker and colleagues (2003) defined the landing time as the time from initial ground contact until maximum knee flexion, whereas in the study of McNitt-Gray (1991) the landing phase ended when the COM reached it’s lowest point. Both of these points are probably closely related, since a greater knee flexion causes the COM to lower.

Some of the available research has specifically focused on volleyball landings (Salci et al., 2004; Tillman et al., 2004; Zahradnik et al., 2015). Salci et al. (2004) used volleyball players as participants. Their results are discussed above in the part about biomechanical differences between women and men during landing. Tillmann and colleagues (2004) investigated the number of jumps and landings that are performed unilaterally versus bilaterally. Their results revealed that volleyball players during game conditions land on both feet most of the time. After offensive jumps (spiking), players land in 55% of the time bilaterally, whereas defensive jumps (blocking) are in 57% caught by two feet. Recently, Zahradnik et al. (2015) compared the 'step-back' landing to a 'stick' landing. In volleyball, there are two types of block, they state. One is a successful block, which is followed by a landing without time pressure, since the play is over. This landing is referred to as a 'stick' landing. When the block is unsuccessful, the play keeps going and the blocker feels time pressure during landing. This landing is called a 'step-back' landing, because right after ground contact the player steps open to get ready for the next counterattack. Comparing these two landing types to each other, results exhibited a similar maximal height of the COM at first ground contact. The first peak of vGRF, caused by the toes to touch the ground, was significantly greater in the step-back than the stick landing for the landing limb, although the knee flexion at ground contact was also greater. The second peak in vGRF was consequently higher in the stick than the step-back landing. An increased risk for ACL-injury was found in the step-back landing, since the maximum knee valgus and external rotation moment were greater under these circumstances and related to ACL-injury.

No research has been found that focused on the differences in landing impulses under different landing circumstances in volleyball. Two common blocking styles are the traditional and swing blocking method and it is of interest to know how these differ, not only during the jumping, but also during landing.

CHAPTER III

METHODOLOGY

For this study, the same subjects and trials were analyzed as in Ficklin et al. (2014). Therefore, the participants and the procedures of collecting video data are identical. Additionally, this implies that the results found there apply to the subjects used in this study.

Participants

Eight female volleyball players (age: 20.9 ± 1.9 years; height: 184.9 ± 4.7 cm; mass: 76.3 ± 7.8 kg) were filmed performing volleyball blocks. All of them were part of a nationally competitive Division I volleyball team. They were fit and injury free when they participated. The subjects volunteered to take part in the study with permission from their coach. Informed consents were signed before data collection and all procedures were approved by the institutional review board.

Procedures

Every subject had 5 minutes to perform a dynamic warm-up, after which there was time to practice both blocking styles until feeling comfortable. The players were introduced to both blocking styles, but they were more used to the traditional blocking style and the footwork pattern that goes with it. Therefore, they needed less time to practice this blocking style. After feeling comfortable with both blocking styles, the subjects performed the experimental trails.

The subjects started the movement from a marked box on the floor (82.5cm wide and 45cm long) in the middle of the long axis of the court and 30 cm from the court's centerline. They started in a ‘ready position.’ This includes slightly bent knees and arms out in front with flexed elbows, so that the palms of the hands are parallel to the net and are at least as high as the face of the player. In game conditions volleyball players take this position. From there the lateral movement was initiated. All blocking movements were performed to the right side. In the traditional blocking style no arm swing was used, so flexion in the elbow-joints was maintained. Players started the footwork with the right foot taking a step to the right side. Then, they crossed with the left foot, which was followed by a lateral jump into takeoff position. In the swing-blocking style an arm-swing was used. The footwork pattern in this style also started with a step with the right foot to the right side, which was again followed by a cross-step with the left foot. The left foot was then at takeoff position and the right foot closed. In contrast to the traditional blocking style, in this movement the axes of the shoulder and hips of the player were mostly perpendicular to the plane of the net. The traditional blocking style and the swing blocking style were performed in a counterbalanced order, to control for a learning or fatigue.

To ensure that during all trials the same distance was travelled, not only the start, but also the end was marked. At a distance of 1.50m from the right antennae blue tape was attached to the net. This created a gap of 3.00m between the starting box and the tape, which had to be travelled during the footwork pattern. The blue tape served as a target for the players. Players were told to jump maximally like if an attack was coming from the blue tape. When participants didn’t succeed to block at this point the trial did not count and had to be repeated.

A successful trial was defined as using the right technique, succeeding at moving the right distance with the blue tape being between the two arms during the whole jumping motion. Every subject performed six successful trials: three with the swing blocking style and three with the traditional blocking style. The best of the three successful trials was determined by the principal investigator and chosen for analysis.

The video of the best trial was exported and digitized frame by frame from IGC until being back in equilibrium. In every frame, the vertex, gonium, sternum, right and left shoulder, elbow, wrist, knuckle, hip, knee, ankle, heel and toe were marked. This information was then exported and saved as a .csv file to derive the center of mass (COM) location in every frame. Using a scale factor, these COM locations were changed from pixels into meters. Subsequent calculations were done on the COM locations to calculate the wanting variables.

Instrumentation

All videos were recorded by video cameras in 1080p high definition mode (JVC GC-PX1), Victor Corporation, Tokyo, Japan) at a frequency of 60 Hz. The cameras were placed behind the end line and perpendicular to the net, on the side of the net were the blocking trials were performed.

Bony landmark positions were located in the video using a digitizing program (MaxTraq 2D, Innovision Systems, Inc., Columbiaville, MI). Hereby, the body was divided into fourteen segments. Custom Matlab software was used to derive the COM positions of the segments and the body after gaining body landmark positions, using procedures described by Dapena (1986). Inertial parameters of the segments were taken from de Leva (1996).

Calculations on the COM positions were conducted using Excel and statistical procedures were done using SPSS (Chicago, IL).

Data Analysis

Based on available literature the landing phase was defined as the time between initial ground contact (IGC) and the moment where the COM reached its lowest point (McNitt-Gray, 1991). Therefore, the landing time was the time between IGC and the frame of COM minimum:

$$T_{landing} = (f_{COM,\ minimum} - f_{IGC}) * 1/60s$$

All analyses were done for the landing phase.

Starting with the position of the COM in every frame, the vertical velocity and the vertical acceleration of the COM were derived frame-by-frame using integration. The following equations were used:

$$v = \Delta s / t$$

$$a = \Delta v / t$$

Using a given number as subject mass and knowing the acceleration, the sum of forces were calculated for every frame using Newton's second law:

$$\sum F = m * a$$

By averaging the sum of forces for the landing time and knowing the time of the landing phase, the landing impulse was calculated:

$$I = \sum F * t$$

Since the subject was only in contact with the ground, the external forces working on the subject's body were the weight of the subject and the ground reaction force. These two forces together make up the sum of forces. The body weight was calculated using the following equation:

$$W = m * g$$

where m represents the subject's mass and g the acceleration due to gravity, which has a magnitude of -9.81 m/s^2 for the purpose of this study. For every subject a mass of 75kg was used.

Thereby, the ground reaction force was:

$$GRF = \sum F - W$$

Digitized data was used to calculate the following variables for the landing phase: position, velocity and acceleration of the COM in every frame, the sum of forces acting on the subject and the impulse made with the ground.

Statistical procedures were conducted using SPSS (Chicago, IL). Paired t-tests were conducted for the height of the COM in its lowest point, landing impulse, landing time, average vGRF during the landing phase and peak vGRF between the two blocking styles of the same subject. A p-value of <0.05 indicated statistical significance.

CHAPTER IV

RESULTS

Descriptive statistics (mean ± SD) of all dependent variables separated by technique can be found in Table 1. The results of the paired samples can also be found in this table. Figure 1 shows the landing impulses for each subject.

Table 1.

Descriptive statistics of all dependent variables for each technique (n=8)

	Swing	Traditional		
	Mean ± SD	Mean ± SD	t	p
Lowest COM (m)	1.32 ± 0.062	1.32 ± 0.061	0.029	0.978
Impulse (Ns)	239.51 ± 23.29	224.98 ± 24.91	3.003	0.020*
Landing time (s)	0.19 ± 0.038	0.19 ± 0.032	-0.188	0.856
Peak vGRF (N)	2924.97 ± 451.80	2707.35 ± 308.76	1.548	0.166
Average vGRF (N)	1300.49 ± 318.51	1201.49 ± 297.49	1.195	0.271

*Denotes a significant difference between the techniques.

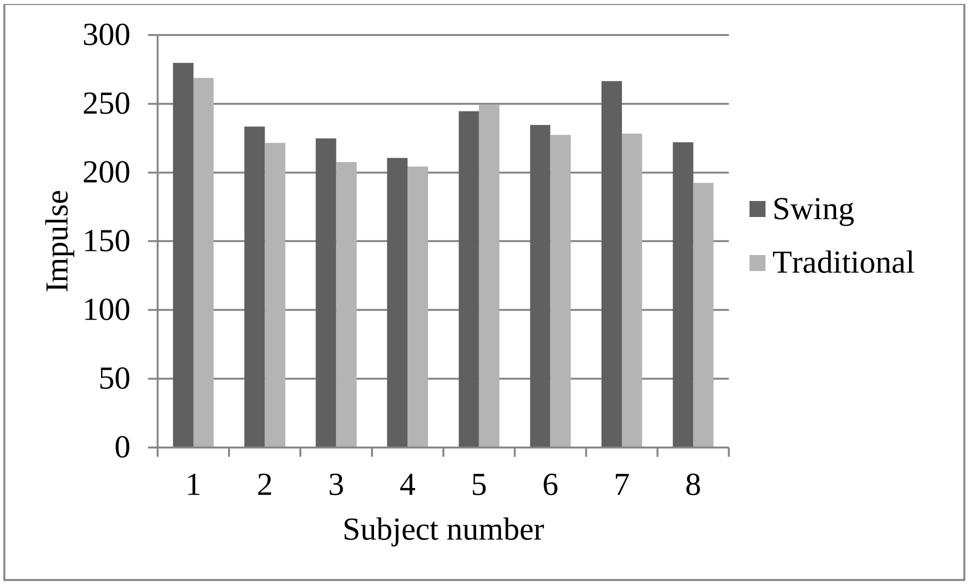

Figure 1: Landing impulses

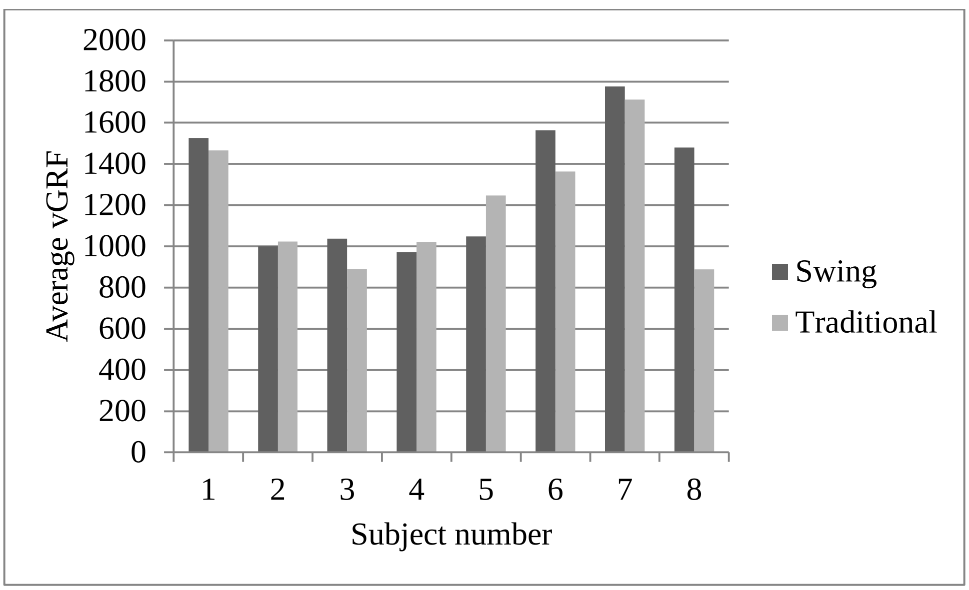

Figure 2: Average vGRF

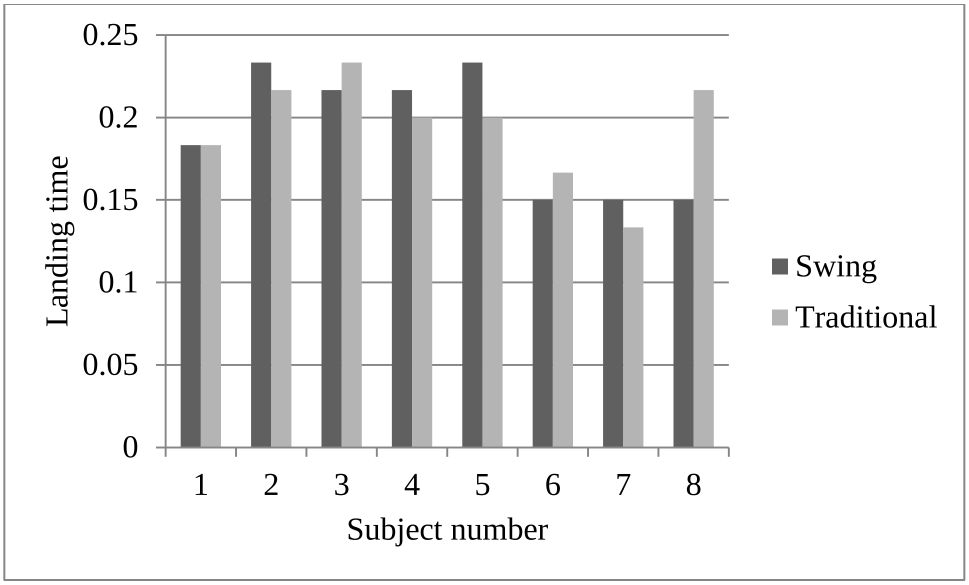

Figure 3: Landing times

CHAPTER V

DISCUSSION

The results of this study reveal that the landing impulse is greater when using the swing blocking technique than the traditional blocking style (Figure 1). This is in accordance with the hypothesis of the study, which stated that the greater jump height, seen in the swing blocking style, would be accompanied by a greater landing impulse. Research has shown that the jump is significantly higher when making use of an armswing (Harman et al., 1990; Lees et al., 2004; Shetty & Etnyre, 1989). This armswing, employed in the swing blocking method, leads to a greater peak jump height in this style (Ficklin et al., 2014; Neves et al., 2011). A greater jump height will lead to a greater velocity at touchdown, which in turn leads to a greater momentum of the subject when touching the ground. Since impulse is the change of momentum, it was both hypothesized and shown that the greater momentum at touchdown would lead to a greater landing impulse.

The second hypothesis was that the greater impulse would either be caused by a greater average vGRF during the landing phase or by a greater landing time. However, none of these two variables were different between the two blocking styles. This was surprising, because an impulse is made up by these two factors. Although both the landing time and the average vGRF were not significantly different when analyzed separately, there must exist a difference in these factors between the groups, which causes the significant impulse-difference when they are analyzed together. The results illustrate that the landing times are very similar between the traditional and swing blocking style (p=0.859). The average vGRF during the landing phase, however, was greater during the swing blocking style (1300.49 ± 318.51N compared to 1201.49 ± 297.49N). This difference, although not statistically significant, must have lead to the significant difference in landing impulse after multiplying it with the landing time. The variability found both in the landing time and in the average vGRF indicate that some subjects will have made the bigger impulse during swing blocking style by applying greater forces and others by using more time. This assumption is supported by the data supplied in figure 2 and 3. Subject 1, 3, 6 and 8 had higher average vGRF during the landing phase in swing blocking conditions, whereas subject 2, 4, and 5 increased their landing times. Subject 7 had both higher average vGRF and landing times when using the swing blocking method. These data show that subjects respond differently to a higher impulse: some increase the average forces and some elongate the time in which forces are applied. As a result the impulse, but not the forces or the landing times, is significantly different between the two blocking methods.

Regarding the risk of injury associated with jumping and lading, it is of interest to know that the peak vGRF does not differ between the two blocking styles. Although the peak vGRF was higher under swing blocking style conditions, this difference was not statistically significant.

Looking from a performance standpoint, it is important to know if volleyball players will spend more time on landing conducting one style than the other. This study reveals that the landing time is similar between the two blocking methods. This means that although athletes jump higher when using an armswing, their landing time does not increase. Taking other available research comparing the different blocking styles into account, athletes using the swing blocking method have greater horizontal and vertical velocities, peak jump height, net penetration and effective blocking area compared to athletes conducting the traditional blocking style (Ficklin et al., 2014; Neves et al., 2011). These findings favor the swing blocking style over the traditional blocking style. The results of this study on landing times do not offer a counterargument, since the landing times are similar between the two styles. A reason why coaches could still favor the traditional blocking style is the sooner takeoff and greater horizontal displacement in the air seen in the swing blocking style (Ficklin et al., 2014).

One of the limitations of this study was that the participants were more familiar executing the traditional blocking style, since this method was preferred by their coaches. Another limitation is that all blocking movements were performed to the right side. Most of the opponent's attacks come from their outside hitter, which requires this block to the right side. However, different results might have been found when performing the movement to the left side. Finally, the circumstances represented in this study are not game-like. Although the participants were asked to jump maximally as if an attack was coming from the other side, game-like feelings and especially a ball were missing in this study. Future research should be done to investigate if the results found here change when the player has to react right after blocking. During competition, the blocker often has to get ready for the next counterattack right after blocking as soon as possible. It is of interest to know if the results found here apply to those situations as well.

To the best of our knowledge, no research has been conducted comparing the landing impulses between different blocking styles. Therefore, the results of this study are new and could have implications on decisions made by coaches about what blocking style to use. The swing blocking style does cause a greater impulse, but the landing time is similar between the methods. Volleyball players spend similar times on landing irrespective of the blocking style, which doesn’t favor one style over the other regarding being ready for the next counterattack.

CHAPTER VI

CONCLUSION

In conclusion, this study revealed new results about the differences in landing impulses between the traditional and swing blocking style in volleyball. Players showed to have a significant greater landing impulse when using the swing blocking method compared to when executing the traditional blocking style. The landing time, however, is similar between the two methods. This means that regarding the time spent on landing coaches can choose between two equal options. There is no technique faster in landing than the other.

Research conducted before has focused on the jumping part of blocking, this study was, as far as we know, the first one to examine the differences in landing between these two blocking methods. This information gives coaches a better idea of all the differences and effects that implementing one style over the other has. All in all, the swing blocking method leads to a greater jump height, penetration over the plane of the net and effective blocking area (Ficklin et al., 2014; Neves et al., 2011). These advantages are supported by the fact that the landing time is similar to when performing the traditional blocking style. All of these results show that the swing blocking style has advantageous effects on the block. Coaches have to make the decision if these advantages outweigh the sooner takeoff and greater horizontal displacement during the airborne phase, seen in the swing blocking style as well.

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