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Validity of the Zephyr Bioharness for Vertical Power Output and Ground Reaction Forces

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Introduction

Anyone who witnessed, either live or on replay, the gruesome leg injury suffered by Louisville men's basketball player Kevin Ware during the Elite Eight round of the 2013 Division I NCAA Tournament will not soon forget the shock and horror they undoubtedly felt at the time. Players and coaches on the court broke into tears and spectators took to social media to express their concern. People worried for Ware as an individual, about his pain, and the potential effect this injury would have on his career. Others expressed concerns about the impact his injury would have on the team and the Louisville community. Still others began to worry about the stress being put on all collegiate athletes and the term "overtraining" (when the stimulus has reached the point where either or both training intensity and training volume has become too excessive and is coupled with inadequate rest and recovery) once again hit the headlines.

There is no doubt that injury to players has a major impact on athletes and their teams, both physically and financially. Colleges are therefore willing to invest in new technologies that might help in efforts to understand and prevent injuries. The NCAA has also tried to help prevent injuries to athletes by limiting practice schedules and types of practice. For example, currently during a Division I basketball season, coaches are only allowed 20 hours per week of practice time. These 20 hours also include weight workouts, film study, and anything else considered mandatory by the coaching staff. However, as of January 2012, the NCAA approved a rule allowing 8 weeks of basketball workouts including no more than 2 hours of skill related instruction per week during the summer for all Division I collegiate basketball programs (except Ivy League because they do not offer summer school). Previously, there were no workouts during the summer months outside of weight and agility workouts, which helped improve the athletes' abilities to prevent injuries. Such agility workouts included instruction and training on how to properly land from jumping as to not put too much stress on the knees and lower limbs. While the new ruling is a welcome change for a number of reasons, it is important not to lose sight of the possible consequences of added practice and stress on the bodies of the athletes. According to Dr. Christopher Lee, an orthopedic surgeon trained in sports medicine, the cause of Kevin Ware's broken tibia during the NCAA Tournament game was most likely due to a bad landing. He speculated in an interview with Crave Online that "If we jump and we land we'll bend our knees… we'll absorb that shock. But his knee literally almost buckled and that basically transmits a ton of force into the bone or joint." This injury could have been prevented if Ware had received training on how to land properly. However, while Ware's injury serves as a graphic example, most injuries to athletes revolve around knee injuries, not broken bones. Dr. Souryal reported that there are about 250,000 to 300,000 ACL injuries per year and the chances of a non-athlete suffering an ACL tear compared to that of an athlete is 1 to 1,000. Much research is being done to try to determine how training programs might help prevent injury (Souryal, 2013).

In a study that examined the effects of a jump and balance training program on knee kinematics, it was found that such programs could possibly reduce the risk of ACL (anterior cruciate ligament) injury. Much of the research is dedicated to studying the physics of jumping and landing and the forces placed on the athletes' lower bodies during such movements. There have been a number of technological advances in recent years designed to help study kinematics that are advertised to help strength coaches monitor and protect their student-athletes. One such device is the Zephyr™ Bioharness, which is a puck-like device that is attached to the athlete's body either by a strap across the chest or a specially designed tight fitting sleeveless shirt with a built-in puck insert compartment. This product is advertised as an effective tool to measure respiratory responses during exercise (heart rate, breaths per minute, and body core temperature) as well as vertical power and g-forces. All of the data taken by the Zephyr™ system are recorded in the puck sensor and transmitted via Bluetooth to a computer that can record, analyze, and save the data. The appeal of this technology is the convenience of being able to monitor a large number of measurements and athletes at the same time and without hindering the athletes' movements. These measurements can prove to be very effective in determining if athletes are being worked too hard. Overtraining, which is defined as occurring "when the stimulus has reached the point where either or both training intensity and training volume has become too excessive and is coupled with inadequate rest and recovery" (Hoffman & Kaminsky, 2000, abstract), can be very detrimental to athletes and can lead to an increase in number of injuries throughout the year. It is widely known that many knee injuries that occur in basketball happen during non-contact plays or movements. It is also clear from studies that knee injuries occur at very high rates due to participation in sports starting from a young age (Swanson et al. 2013). The study found that knee injuries occurred at a rate of 2.98 knee injuries per 10,000 athlete exposures, with football at the highest rate, followed by women's soccer and gymnastics. It was also found that women tend to suffer significantly higher rates of knee injury than men. It is important to be able to monitor the amount of force being placed on athletes in order to prevent injury and increase performance.

Collegiate sports, especially major Division I programs, are centered on winning and every program looks for ways to gain an advantage over the competition. Strength coaches around the country are eager to try new technologies like the Zephyr™ to give their athletes this advantage. One measurement of athletic performance is the vertical jump, which is part of the field known as plyometrics or jump training. Athletes with higher vertical jumps and those with the ability to land and jump quickly and effectively have a definite advantage over those who cannot. Basketball, in particular, requires an above average vertical jumping ability, which is best measured in terms of vertical power output and ground reaction force. Both are measured by the Zehpyr™. This new technology certainly seems to offer an excellent way for measuring these important aspects of athletic performance, but as is the case with any new technology, it must be tested for accuracy alongside a preexisting and accepted method of measurement. While the effectiveness of the respiratory response measurement has been validated previously (Hailstone and Kilding, 2011), the effectiveness of the Zephyr™ Bioharness in regards to vertical power and ground reaction forces has not. This study aims to explore the validity of the Zephyr™ BioHarness in its claim of effectively measuring the vertical power and g-forces of athletes. In order to do so, measurements recorded by the Zephyr™ will be compared with measurements found using the traditional method of performing a jump test on a force plate.

Literature Review

Injury

Much research is being conducted to help better understand knee injuries. Possibly not a single basketball program has survived untouched by ACL injuries that often lead to major surgery and months of rehabilitation. According to Kujala et al. (1995), most injuries occur in athletes between the ages of 20 and 24 and knee injuries are the most common cause of permanent disability. It is important to find ways to reduce this risk of injury. The authors recommended that sports should implement rules and regulations that limit violent contact and they also recommended sport specific preventative measures. Such measures have been seen today in collegiate and professional football. There have been rule changes in regards to hitting defenseless players and the types of tackles that are allowed. Despite rule changes and the added interest in sports injuries, the number of sports-related injuries continues to rise. Probably the most common sports injury, or at least the most famous, is the anterior cruciate ligament tear, commonly known as an ACL tear. Many ACL injuries occur during non-contact plays or movements. A lot of attention has been given to analyzing landing techniques and movement patterns that will allow the athlete to accelerate and decelerate efficiently and safely. Sell et al. (2006) conducted a study that centered on ground reaction forces, joint kinematics, joint kinetics, and electromyographic activity, it was concluded that lateral jumps are the most dangerous in regards to non-contact ACL injuries. Kar and Quesada (2013) studied the underlying causes of ACL injuries during stop jumps and non-contact activities. The authors studied factors such as knee valgus loads and knee anterior-posterior forces that they believed to be the cause of such injuries. They found that detriments to ACL stability involved a lack of symmetry for valgus angles, valgus moments and muscular activations. In basketball, there are many situations in which multiple jumps are necessary to be effective. One such example is jumping continuously while fighting for a rebound. Bates, Ford, Myer, and Hewett (2013) went even further and tested not only the first landing of a jump test, but also the second landing. The second landing refers to an athlete's second jump landing after the initial drop vertical test in which the athlete drops down from a specified height and jumps just after making contact with the ground. The authors stated that the second landing is often ignored and most data have been taken only on the first landing. They found that the second landing "demonstrated smaller flexion angles and moments at the hip and knee than the first landing. The second landing also demonstrated greater side-to-side asymmetry in hip and knee kinematics and kinetics for both the frontal and sagittal planes" (Bates, Ford, Myer, and Hewett, 2013, abstract) The authors concluded that the second landing is a more rigorous task and a better tool to evaluate knee injury risk factors in the sagittal plane. In addition to landing research, studies have also shown the relationship between overtraining and increased injuries. One such study mentioned in the introduction by Hoffman and Kaminsky (2000), concluded that overtraining can be caused by the failures of coaches and athletes to heed repeated warnings from the body. Other factors that contribute to overtraining include the environment in which the athlete trains, the training program, nutritional factors, and psychological issues. The authors advised a recovery period for athletes that could prevent overtraining and lead to improved performance in the long run. The training program in basketball may in itself have a major impact on the likelihood of injury and illness. Anderson, Triplett-McBride, Foster, Doberstein, and Brice (2003) conducted a study based on questionnaires given to collegiate women's basketball players throughout the season to document the occurrence of injury and illness relative to the intensity and duration of practice. It was concluded that the times of higher intensity and duration of practice coincided with increased illness and injury.

Training

Strength coaches across the country train their athletes using methods designed to prevent injury. Many strength-training programs begin their training season with a full body screening that is used to determine each athlete's individual strengths and weaknesses. One study conducted by Dallinga, Benjaminse, and Lemmink (2012) aimed at determining the effective screening tools for preventing injury to the lower extremities. The study found that the Star Excursion Balance Test (SEBT) may be a good predictor of leg injuries based on its measurements in the anterior right and left reach distance and composite reach distances of limb length. It was also found that a decreased range of hip abduction motion, a low hamstring to quadriceps ratio, and increasing age were correlated to increased incidence of leg injuries.

One of the most important training adaptations to preventing injury is an effective warm-up program. No collegiate workout is performed without a proper warm-up prior to engaging in athletic activity. A systematic review undertaken by Herman, Barton, Malliaras, and Morressey (2012) determined that warm-up strategies involving stretching, strengthening, balance exercises, sport-specific agility drills, and landing techniques that were applied for more than three months were the most effective in preventing injury. Another tool for preventing injury could simply be direct instruction. When an athlete is taught the proper way to perform a task, they are less likely to make a mistake that could cause them injury. Tate, Milner, Fairbrother and Zhang (2013) conducted a study to measure how effective home-based instruction could be for improving frontal plane knee biomechanics during a jump-landing task. They found that explaining the proper techniques for jumping and landing during a jump-landing task resulted in a greater knee flexion angle, but results did not show improvement in the frontal plane movements. Rather, they found that improvement was limited to the sagittal plane movements. Jump and balance training seems to be a very good way to help avoid ACL injuries. Nagano, Ida, Akai, and Fukubayashi (2011) supported this by testing eight female athletes at three different times over a period of six weeks. The athletes performed a single limb landing and also participated in a jump and balance program. Specifically "knee kinematics and simultaneous electromyography of the rectus femoris and hamstrings before training were compared with those measured after completing the training program." The study provides conclusive evidence that jump and balance training does have a positive impact.

Male vs. Female

Many of the studies mentioned above focused on either male or female athletes or a combination of both. Other studies conducted have aimed at determining differences between males and females in terms of proneness to injury. In general, females tend to have a higher rate of knee injuries than males, as was reported by Swenson et al. (2013). One study performed by Ford, Myer, and Hewett (2003) analyzed valgus knee motion during landing and compared high school female and male basketball players. They determined that females had increased valgus knee motion, which causes decreased joint control in the coronal planes and therefore creates a higher risk for knee injury. Similarly, Decker, Torry, Wyland, Sterett, and (2003) sought to determine why female athletes have a tendency for more ACL injuries than their male counterparts. In this particular study, participants performed multiple jump tests to find differences in joint motions and energy absorption landing strategies. Females tended to have a more erect posture (legs straight and body not bent and/or braced for impact) upon landing and exhibited a greater range of motion in the hip and ankle joints, which put greater stress on the ACL.

Human Power Output/Ground Reaction Forces (GRFs)

For the purposes of this study, the most important factors in injury prevention and improved athletic performance are human vertical power output and ground reaction forces. Vertical power is defined as the ability to exert maximal strength quickly and forcefully in a vertical plane. As previously stated in the introduction, such an ability is very important to many sports, especially basketball, in which athletes rely on being able to jump high and jump quickly. Ground reaction forces are also important to understand and measure because the amount of impact caused by the athlete hitting the ground when landing from a jump puts tremendous stress on the lower extremities. A number of techniques for measuring power output and GRFs have been tested for their validity and reliability. To estimate human power output from a vertical jump, the Lewis Formula has been a widely used method. The Lewis Formula is defined as (P =

$\sqrt{4.9} \times BM \times \sqrt{h_j}$) where BM is the body mass in kilograms and h_j is the height of the vertical jump in meters (Johnson & Bahamonde, 1996, p. 161). Even though this method was a widely used method, in 1991 Harmon, Posenstein, Fykman, Rosenstein, and Kraemer determined that the Lewis Method was not accurate for estimating the peak and average power output in a vertical jump. The most effective method to measure vertical power output is to have a subject complete a jump test on a force plate.

The height from which a vertical jump is performed affects the amount of ground reaction forces created when landing. The study, "Ground Reaction Forces Among Gymnasts and Recreational Athletes in Drop Landings" measured and compared the GRFs of gymnasts and recreational athletes during drop landings from a series of heights and found that the greater heights produced significantly higher ground reaction force values, which the authors contributed to incidence of lower extremity injuries (Seegmiller & McCaw, 2003). GRFs are created each time a person walks, jogs, or runs and makes contact with the ground. According to Keller et al. (1996), impact forces in these simple movements are greatest when the subjects jog slowly with a higher and less fixed center of gravity. But more than these simple movements, what aspects of ground reaction force pertain specifically to knee injury? In basketball and many other sports that require continuous movement both laterally and vertically, reducing ground reaction forces is key to reducing knee injury risk. Burnett (2008) concluded that due to the amount of stress put on the lower limbs during jumping, injury is inevitable. How severe the injury is and when it will occur depend on how resilient the athlete's body is. When an athlete jumps and lands on a hard, artificial surface (like hardwood in basketball), the bones, tendons, fascia, and ligaments of the legs are forced to bear the load (Burnett, 2008). Because of this, an effective method for measuring the load placed on the body is very important. Accurate measuring tools, such as the

Zephyr™ Bioharness, can be instrumental in measuring GRFs. However, as mentioned earlier in my introduction, new technology should be validated for accuracy. To date, the only validation done on the Zephyr™ product has been on its reliability and validity in regards to measuring respiratory responses during exercise (Halistone and Kilding, 2011). Therefore, the aim of the present investigation is to determine if the product is also valid for measuring vertical power and ground reaction forces.

Methodology

In order to measure the validity of the Zephyr Bioharness, its effectiveness must be compared against a known valid measurement technique. In the case of this study, a force plate was used to determine the amount of ground reaction force produced by the participants and the g-forces placed on the athlete upon jumping. When a participant jumped and landed on the force plate, the plate recorded the amount of force caused by the landing of the participant. The force plate also recorded the average force of the entire jump, including the force created when the participant gathered himself to jump. These measurements were then compared to the values logged by the Zephyr™ and it was possible to determine if the values were consistent and therefore valid. The participants in this study were 10 male Division I SEC basketball athletes from the University of Arkansas Men's Basketball Team as well as 10 volunteer recreational athletes from the university. The purpose of using both Division I athletes and recreational athletes was to determine the difference in amount of force produced by the landing of physically trained individuals compared with less trained recreational athletes. This also served to determine if the Zephyr™ was more effective and/or valid for the everyday athlete or Division I competitive athletes.

The actual test was a simple two-foot jump vertical test. First, each participant was put through a series of warm-up activities that involved stretching and movement preparation so that each participant was able to exert full effort. Such exercises included dynamic stretching to prepare the muscles for activity, as well as a series of warm-up activities to make sure all participants were loose and therefore reduce the risk of potential injury. Next, each participant received instruction on proper technique for a two-foot vertical jump and how to land properly. Such instruction included how to stand with feet at shoulder-width apart and how to squat down and then explode upwards using the arms to propel the body to maximum height. It is important to note that while squatting down to prepare to jump, participants were prompted to move their hips back in order to take pressure away from the knees. This also was a way to reduce the risk of injury during testing. Also, this gave the participant enhanced balance during the jump and allowed an accurate landing on the force plate, as no data could be recorded if the participant did not land on the force plate. Each participant was allowed two practice jumps before measurements were recorded.

The participant stood on the force plate with the Zephyr™ Bioharness strapped to their chest, jumped vertically, and landed directly on the force plate. Each participant was allowed to jump three times. Once the three jumps were completed, that portion of the test was over and the data was recorded. This was repeated with all 20 participants. The purpose of wearing the Zephyr™ system at the same time as jumping onto the force plate was that it made it easier to compare the data and there was no difference in effort of the athlete, which could be a factor if two separate tests were done instead.

During data analysis, the third jump of every test was used to determine if the values had significant correlation. Only the third jump was used because it was observed to be the most accurate representation of the participant's jump because the participant had two prior chances to correct mistakes in their jump and make sure they properly landed on the force plate.

Following the data collection, the results were compared and the percent error and percent difference between the values given by the Zephyr™ and by the force plate were analyzed to conclude whether or not the system was valid. Values were taken from the force plate (amount of force produced by the athlete when he/she jumps were calculated) and were compared to the g-forces placed on the athlete given by the computer program that accompanied the Zephyr™.

Results

The two groups of data (Athletes and non-athletes) were analyzed to determine if there was correlation between the values of the Zephyr™ and the force plate. The researchers ran the data multiple times using different combinations of data in order to determine if the two tools gave similar data. These combinations included the correlations between the Zephyr™ and the maximum value of the force plate on the third jump of the athletes only, between the Zephyr™ and the maximum value of the force plate on the third jump of the non-athletes only, between the Zephyr™ and the average value of the force plate for athletes only and non-athletes only, and the correlation between the Zephyr™ and the force plate for both sets of participants.

Table 1

Correlation Between Zephyr BioHarness™ and Force Plate Average Force in Athletes

		Jump 3 Zephyr	Jump 3 GRF Avg
	Pearson Correlation	1.00	.931
Jump 3 Zephyr	Sig. (2 Tailed)		.000
	N	10	10
	Pearson Correlation	.931	1.00

Jump 3 GRF Avg	Sig. (2 Tailed)	.000	
	N	10	10

The above table shows the data of the correlation between the Zephyr™ reading on the third jump of the vertical jump test and the average force reading from the force plate on the third jump in the collegiate athletes group. There was a clear positive correlation between the two sets of data. The correlation value of r =.93 indicates a strong correlation between the data given by the Zephyr™ and the force plate. Also, the significance value of $p = .000$ indicates that this correlation is statistically significant ($p \leq .05$ is statistically significant). It is important to note that this is the average force given by the force plate and not the maximum force at landing. This average value takes into account not only the landing, but also the force created by the gathering phase of the jump. This indicates that the Zephyr™ was an effective tool to measure the force placed on an athlete during a jump.

Table 2

Correlation Between Zephyr BioHarness™ and Force Plate Average Force in Rec. Athletes

		Jump 3 Zephyr™	Jump 3 GRF Avg
	Pearson Correlation	1.00	.124
Jump 3 Zephyr	Sig. (2 Tailed)		.734
	N	10	10
	Pearson Correlation	.124	1.00
Jump 3 GRF Avg	Sig. (2 Tailed)	.734	
	N	10	10

Table 2 displays the correlation between the values given by the Zephyr™ on the third jump of the test and the average force values given by the force plate for the third jump. The data indicate that there was a weak positive correlation (r = .12) between the Zephyr™ values and the force plate values. The significance value was $p = .73$, which indicates that the data was not statistically significant as the p-value was not $p \leq .05$. These data indicate that the Zephyr™ was not effective for tracking the force placed on the body during a single jump for recreational athletes.

Table 3

Correlation Between Zephyr™ BioHarness and Force Plate Max in Both Groups

		Jump 3 Zephyr	Jump 3 GRF Avg
	Pearson Correlation	1.00	.399
Jump 3 Zephyr	Sig. (2 Tailed)		.081
	N	20	20
	Pearson Correlation	.399	1.00
Jump 3 GRF Max	Sig. (2 Tailed)	.081	
	N	20	20

Table 3 shows the data from the test run to determine the correlation between the Zephyr™ readings and the maximum force plate values for both groups. The correlation value was r =.39, which indicates a moderate positive correlation. The significance value, p = .081, indicated that the correlation was not statistically significant. This indicated that the Zephyr™ was not an effective tool in tracking the amount of force placed on the body in a single jump for all users.

Discussion

Overtraining is a major problem in college sports as coaches are under extreme pressure to win at the highest level, and therefore are forced to work their players at a rate and level that is unhealthy for their bodies. Many programs around the country have adapted to such strenuous schedules and have implemented ways to help protect their athletes from injury. Many programs provide sports massages for their players to help prevent injury and soreness, and all programs have athletic trainers that attend every team event in case an athlete becomes injured. Still, there is no substitute for resting athletes effectively. Part of the problem of overtraining is that athletes are afraid to mention to their coaches and staff when they are injured or feel at risk for injury due to the stigma of "macho" athletes. Male athletes are not supposed to complain, rather they are supposed to "rub some dirt" on an injury and keep going. Recent NCAA rules allowing workouts in the summer have further compounded the overtraining problem. Now, more than ever before, athletes are pushed to work out countless hours throughout the year. Although many athletes may appear completely healthy, it is impossible (without x-ray or MRI) to tell what problems have occurred under the skin and are not visible to the naked eye. Several tools have been developed that claim they can track the amount of force placed on an individual athlete during workouts. One such tool is the Zephyr™ BioHarness, the centerpiece of the study.

After putting the 20 participants through the vertical jump test, the data gave a mixed answer for whether or not the Zephyr™ was an effective and valid tool for determining the amount of force placed on the athlete during a jump. The participants in this study were separated in to two groups, 10 recreational athletes and 10 collegiate athletes. The data from the Zephyr™ was compared to that of the force plate. The researchers found that for the recreational athletes, the Zephyr™'s data did not have a statistically significant correlation with the data given by the force plate. This led researchers to the conclusion that the Zephyr™ is not an effective tool to measure the force placed on the body in a single jump for recreational athletes. However, there was one correlation found that indicated the Zephyr™ was an effective tool. That correlation was between the data given from the Zephyr™ and the data from the force plate of the average force of the jump. The data showed that the correlation value was .931 and the significance value was $p = .01$. The average force includes the force the participants produced when gathering themselves in preparation for the jump. It is also important to note that the Zephyr™ data can be used to predict force for all users because when the data given by the force plate increased, the data from the Zephyr™ increased as well. This enables the user to see a higher or lower force in the jump, but the numbers were not found to be interchangeable. In other words, when the data from the Zephyr™ was converted to Newtons (units for force given by force plate), the numbers did not match, but when the force plate gave a higher reading, the Zephyr™ also gave a higher reading. This led researchers to the question of why the data were statistically significant only for the collegiate athletes.

Possible reasons for the correlation of data with athletes is that athletes, due to their strenuous training throughout their careers, have developed specificity of training to the activities involved in the game of basketball. One such activity, and perhaps the most important, is the vertical jump. Also, these athletes have been taught the proper techniques of jumping and landing. Such techniques include standing with the legs separated at shoulder length apart, squatting with their arms back, using their arms to propel them upward, landing squarely on both feet, and landing with the hips back in order to land softly and take stress off of the knees. The researchers gave these instructions to all participants, including the recreational athletes, but these techniques take time to perfect. Because of this, researchers noticed that the athletes were able to land properly, while many of the recreational athletes struggled to land on two feet directly on the force plate. This is a possible explanation for why the Zephyr™ was more accurate for the athletes. Furthermore, the athletes exhibited a much higher vertical jumping ability. Because the force plate tracks the time in the air, this could have led to the more accurate readings of the average force of the jump. It is also important to discuss the fact that the Zephyr™ is better suited for tracking the force placed on the body during multiple jumps and throughout an entire workout. "Internal accelerometers measure absolute movement of the device. If a subject is inactive, but in an environment which exerts forces on the device e.g. almost any mode of transport, then indicated activity level will reflect the motion of the vehicle rather than the subject" (Bioharness™ 3.0 User Manual, 36). This indicates that any force placed on the device will be recorded, which could have led to inaccurate data in the study. This study was designed to test the Zephyr™ during a single jump, in which the researchers found that it was only accurate for the average force of the jump in the athletes only.

One of the limitations of this study was the inability to track the height of the vertical jump at the same time as tracking the force data. This was due to the fact that jumping and touching the vanes on the Vertec™ made it almost impossible to land directly on the force plate with two feet. This is because reaching with one hand at the top of ones jump, forces the feet to move forward and makes it very difficult to land squarely on two feet. Because of this, the researchers decided to not include the vertical jump height of the participants in the study. Another limitation to this study was the sample size. The data could have proved to be more or less accurate if the sample size was increased. The researchers did not have the means to recruit more collegiate basketball athletes and were forced to keep the sample size to a minimum. This could have had an effect on the findings of the research. It would also be interesting to be able to track the differences between male and female athletes as data has indicated that female athletes are at higher risk for knee injuries. Many believe this is due to the way in which females land and the valgus movement of their knees during landing.

There have been many studies done with the Zephyr, but this study was unique in that it tested the Zephyr™'s accuracy or validity for a single jump. Other studies have used the Zephyr™ to track athletes' performance throughout a season or an offseason and did not take data from single jumps, rather entire workouts. One such study was conducted by Zephyr™ with two high-level college basketball players, one a junior and one a freshman. The data taken was based on the athletes' "Peak Performance" (load and stress placed on the athlete) and the athletes' amount of fatigue (given by the Zephyr Bioharness™'s ability to track heart rate, body core temperature, and breaths per minute). Only forces above 2 G's were taken into consideration in this study. It was found that the junior athlete exhibited more power production and less fatigue than his freshman counterpart. The Zephyr™ gave data for all movents up, down, left, right, forward and backward, as well as the average peak force produced. These data was used to help determine the level at which each athlete was able to perform and the amount of fatigue he experienced (Johnson, 2013, p.6-7). Similar studies have tested the effectiveness of the Zephyr™ in other sports. The Zephyr™ was used to track the performance of an athlete during a 60 yard sprint. The first time recorded for the sprint was 6.38 seconds and the second time recorded was 6.33 seconds. With the help of the Zephyr™ and its ability to track movements, and the force of those movements, in all directions, were able to determine that during the faster time, the athlete exhibited a lower average rise time from the ground, a shorter length of acceleration, and higher average peak forces (recorded in G's). Because of these data, the athlete was able to work on these skills and after a 3-week strength and power-training course, he was able to produce faster times and increased his explosiveness by 25% (Johson, 2013, p. 4).

Although the Zephyr BioHarness^{TM} was not a very effective tool for measuring the force at landing of a single jump, it was effective for the average force produced at landing by athletes. Still, its main purpose is to track the performance of athletes during entire workouts with multiple movements in all directions. It is very effective in this regard, according to studies conducted by other researchers. The ability to track the amount of stress put on athletes gives coaches and trainers around the world the ability to properly train their athletes or clients without overtraining them and potentially injuring them.

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