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RELIABILITY OF THE TURNING POINT CORE TRAINER AS A MEASURE OF SHOULDER HIP SEPARATION ANGLE, SHOULDER ANGULAR VELOCITY, AND HIP ANGULAR VELOCITY DURING VOLLEYBALL SPIKING ACTIONS

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ABSTRACT

Separation of the shoulders and hips is an important contributor for rotational sports such as baseball and golf. Most recent has utilized Motion Capture technology. A new instrument has been developed as a tool to measure separation angle and can also be used to train the core musculature. The primary aim of the current study was to examine the reliability of shoulder hip separation angle (SH_{SA}), shoulder angular velocity (S_{AV}), and hip angular velocity (H_{AV}) as measured using the Turning Point Core Trainer (TP) during volleyball spiking actions. Voluntary participants included 14 collegiate, Division I, female volleyball players from the University of Utah, ranging from 18-30 years of age. Participants completed 10 volleyball spike actions will fastened to the TP. SH_{SA} was calculated at the height of the back swing. Participants were asked to provide maximal velocity during the forward phase thus providing S_{AV} and H_{AV}. Analysis for reliability demonstrated high Cronbach's alpha coefficients across the 10 SH_{SA}, S_{AV}, and H_{AV} (a =.98; a =.91; a =.94), respectively, indicating excellent internal consistency reliability for the TP. Follow-up research should examine whether or not training female outside hitters to increase SH_{SA} at the top of the back swing, will increase SBV during either DL or DAC spikes. The TP measure of-axial rotation during spiking the internal consistency of the measures was high.

Keywords: Volleyball, Spike, Reliability, Torso rotation, Hip rotation, Velocity, Measurement.

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Contribution/ Originality

This study contributes to the existing literature regarding test re-test reliability using the Turning Point Core Trainer to assess torso rotation and the impact it has on sports performance.

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1. INTRODUCTION

The baseball pitch, golf swing, and tennis serve are typically called rotational sport skills because shoulder-hip separation angle (SH_{SA}), shoulder angular velocity (S_{AV}), and hip angular velocity (H_{AV}) have been shown to be crucial for generating high ball velocity (Cohen *et al.*, 1994; Stodden *et al.*, 2001; Myers *et al.*, 2008). More recently, the importance of rotational variables on spiked ball velocity (SBV) has been identified (Brown *et al.*, 2014). Brown *et al.* (2014) examined the influence of SH_{SA}, S_{AV}, H_{AV} on SBV for down-the-line (DL) and diagonally across-court (DAC) spikes in collegiate female volleyball players. The results revealed significant relationships between SBV and SH_{SA}, S_{AV}, H_{AV} for the DAC spikes, with regression analysis revealing S_{AV} as the most important predictor of SBV.

The baseball pitch, golf swing, and volleyball spike, are similar in that high velocity must be transferred to the ball for successful skill execution. During the baseball pitch, Stodden *et al.* (2001) observed faster pitches occurred in trials in which participants displayed the greatest transfer momentum to the ball due to the sequencing of the pitching movements. In golf, Myers *et al.* (2008) investigated the roles of shoulder and hip rotational sequencing and velocities on ball velocity. The results indicated that the difference between the sequencing of shoulder and hip rotation (also known as the x-factor; as seen in Figure 1.), is a more important contributor to ball velocity than the magnitudes of the shoulder and hip angular velocities.

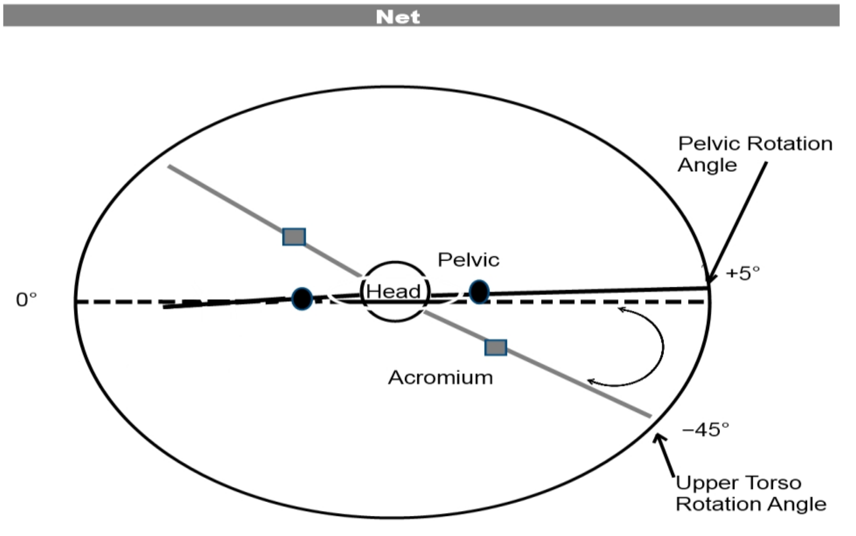

Figure-1. Illustration of the shoulder hip separation angle

Understanding the importance of SH_{SA}, S_{AV}, and H_{AV} has been possible due to the use of cinematography or three-dimensional (3-D) motion capture (Shahbazi-Moghaddam *et al.*, 2002; Brown *et al.*, 2014). Unfortunately 3-D motion capture can only be used for evaluating rotational skills in a laboratory setting, due to the expense of the equipment, and time and knowledge required to do the calibration and the analyses (Karduna *et al.*, 2001; Zhang and Hsiang, 2008).

In addition, 3-D motion capture is not designed as exercise training device. Therefore, there is a need for a more practical, reliable, and valid tool for assessing SH_{SA}, S_{AV}, and H_{AV}.

The Turning Point Core Trainer (TP) is a new tool developed and marketed for developing the strength and range of motion of the body's core muscles. The TP is also capable of quantifying SH_{SA}, S_{AV}, and H_{AV}. Furthermore, SH_{SA}, S_{AV}, and H_{AV} values are available to athletes and sport conditioning coaches (SCC) in real time and do not require lengthy time periods for analysis. If these values are reliable and valid, the TP could be a quicker and cheaper alternative for assessing rotational values. In addition, the TP may help athletes strengthen the core musculature and enhance SH_{SA}. Field measurements of SH_{SA}, S_{AV}, and H_{AV} are not useful if the SCC lack confidence in the measurements. The trustworthiness or level of confidence, of a measurement tool's results is associated with the tool's reliability and validity (Barker *et al.*, 2006). Although reliability and validity are distinct concepts, they are related; for example, a measurement cannot be valid if it is not reliable, whereas a reliable measurement may or may not be considered valid (Barker *et al.*, 2006). Consequently, reliability is a prerequisite to a measurement's validity and is the degree or extent to which a score or measure is free of measurement error (Kaplan and Saccuzzo, 2008). Two different types of reliability exist: test-retest and internal consistency reliability. Both can provide reliability evidence for the TP device; however, the focus of this investigation is to provide evidence for the internal consistency of the TP. Internal-consistency reliability (trial-to-trial reliability) is concerned with assessing random variation over trials (Kaplan and Saccuzzo, 2008). The internal-consistency reliability will inform the SCC if there is consistency in scores over trials within a test. A practical example in volleyball would be if a volleyball coach would like to establish the SH_{SA} of the spiker at the beginning of the season. The coach might have the spiker execute five TP spike simulations. If those five values are not statistically different from one another, resulting in similar SH_{SA} values, then the test is considered to have internal-consistency reliability. Because the TP is a new measurement tool, its reliability must be established, particularly during efforts to create peak SBV. Therefore, the primary aim of the current study was to establish preliminary evidence for the internal-consistency reliability coefficients of the TP as a measure of SH_{SA}, S_{AV}, and H_{AV} during volleyball spiking actions. We hypothesized that the TP will have high internal consistency reliability coefficients as a measure of SH_{SA}, S_{AV}, and H_{AV} during volleyball spiking actions.

2. METHODS

2.1. Participants

The 14 participants in the current study were collegiate, Division I female volleyball players, ranging from 18-30, who voluntarily participated. All the players were from the Women's volleyball team at the University of Utah. Players with either acute or chronic injuries that interfered with their volleyball spiking capability were excluded. In addition, this study has been approved by the Institutional Review Board (IRB) at the University of Utah.

2.2. Study Design

This reliability study used a convenience sample of female collegiate volleyball players. Each player, after a self-selected warm-up, executed a total of 10 volleyball spiking actions while positioned in the TP for the purpose of examining the internal consistency reliability of the TP.

2.3. Study Instruments and Procedures

During the off-season and prior to pre-season fitness testing sessions, athletes were measured for anthropometric data with athletes wearing lycra shorts, sports bras, and a swim cap. Height was measured to the nearest 0.1 cm using a stadiometer, body mass was measured within 0.01 kg on a calibrated electric scale, and body composition was assessed using Air Displacement Plethysmography (Bod Pod, Life Measurement Inc., Concord, CA). The Siri equation was used to calculate percent body fat. Equipment was calibrated prior to testing according to manufacturer's recommendations (Dempster and Aitkens, 1995; Fields *et al.*, 2002).

2.4. Measuring Rotational Variables

The TP was designed to evaluate and develop function of the body's core muscles. In addition to instantaneously measuring range of motion of the upper torso and hips, the TP measures rotational velocities as well as the timing of the separate movements of the upper torso and hips. By providing instantaneous feedback and the option of applying variable resistance, the TP can be used to train the sequencing of the upper torso and hips for rotational sport skills like the volleyball spike if the TP output is reliable.

For the current study, each participant performed 10 volleyball spiking actions while positioned in the TP. SH_{SA}, S_{AV}, and H_{AV} for each of 10 volleyball spiking actions were recorded (Health Industries, Inc., West Jordan,). The TP spiking actions were done in the Human Performance Research Lab in HPER at the University of Utah. Investigators adjusted the height of the TP arms so that the horizontal arms of the TP were at shoulder level near C-7 spine. The TP hip pads were adjusted so that they were firmly positioned at the level of the participant's anterior superior iliac spine (ASIS). Forward trunk inclination was set to 0° of trunk flexion with the participant's foot placement adjusted to hip width while standing facing forward. This position was considered the neutral position.

Prior to the TP spiking actions, the participants were instructed to perform a self-selected warm-up and perform three practice spiking actions on the TP. Once re-positioned in the neutral position on the TP, participants performed 10 spiking action repetitions with a 30-second recovery between repetitions. Participants were instructed to initiate the backswing rotation from the neutral position with their dominant arm followed with the forward swing used in spiking. The TP provides the option for variable resistance; however, all the spiking actions were performed at zero resistance. Participants were encouraged to perform all spiking actions with maximum speed and force (Kaplan and Saccuzzo, 2008).

In order to calculate SH_{SA}, the highest value for the upper torso and hip rotational angle at the top of the backswing was identified and subtracted from the highest upper torso rotational angle. S_{AV} and H_{AV} were calculated by taking the highest S_{AV} value and H_{AV} value that occurred during the forward rotation of each spiking action.

2.5. Statistical Analysis

In order to examine the internal consistency reliability of the TP as a tool for assessing SH_{SA}, S_{AV}, and H_{AV} during the spiking actions, Cronbach's alpha coefficients (a) were calculated. All values for the SH_{SA} 10 spiking action trials were used to calculate a Cronbach's alpha coefficient. The same calculation was completed for the 10 S_{AV} values as well as the 10 H_{AV} values.

Measurement precision (repeatability) across the 10 SH_{SA} values was determined by calculating the within subject coefficient of variation (CV), and standard error of measurement (SEM) to determine between subject variation (Aragon-Vargas, 2000). These same determinations were completed for the 10 S_{AV} values as well as the 10 values. The CV was calculated by using within subject standard deviation of the data, divided by the mean and multiplied by 100 to give a percentage score for each individual. The SEM was computed by using the group standard deviation (SD) and the Cronbach's alpha coefficient, an error estimate of reliability across trials.

The stability of the 10 SH_{SA}, S_{AV} and H_{AV} values was determined by using a two-way factor mixed (participants random and trials fixed) repeated measures factorial ANOVA. For all analyses, an alpha (*p*) of < 0.05 was used to denote statistical significance. All data were compiled on collection sheets and analyzed using Excel 2007 and PASW Statistical software18.0 (Formerly SPSS; IBM Inc., Chicago, IL).

3. RESULTS

3.1. Participants Characteristics

A total of 14 female collegiate volleyball athletes, between the ages of 18-30 years, were successfully recruited from the University of Utah. Six players were outside hitters, 3 were middle blockers, 3 were setters, and 2 were liberos. All but one of the players was right handed. Means, ranges, and SD were determined for all variables. The players had played at the collegiate level for an average of 3.2 ± 1.4 years. The demographic data for age, weight, height, body fat percentage, fat free mass, fat mass, and body mass index are presented in Table 1.

Table-1. Descriptive Data for the Sample of 14 Female Collegiate Volleyball Athletes

Variable	M ± SD
Age (yrs)	20.9±2.8
Height (cm)	181.6±7.7
Body Mass (kg)	72.9.3±12.5
Body Mass Index (kg/m²)	22.0±3.0
Body Fat % (ADP)	22.0±6.3
Fat Free Mass (kg)	56.3±7.0
Fat Mass (kg)	16.5±7.5

3.2. Reliability of TP Data

All volleyball spiking actions were performed on the TP. The descriptive statistics for each of the 10 trials for the SH_{SA}, S_{AV}, and H_{AV} during volleyball spiking actions are presented in Table 2. The internal consistency reliability coefficients, for SH_{SA}, S_{AV}, and H_{AV} across the 10 trials, determined using Cronbach's Alpha (a =.98; a =.91; a = 94, respectively), are reported in Table 3. Mean and SD, and SEM across the 10 SH_{SA}, S_{AV}, and H_{AV} are also reported in Table 3.

The stability across trials of the 10 SH_{SA}, S_{AV}, and H_{AV} was determined by using a two-way mixed factor (participants random and trials fixed) repeated measures factorial ANOVA. The results of the ANOVA analysis are reported in Table 4.

Table-2. Means and Standard Deviations for SH_{SA}, S_{AV}, and H_{AV} During Volleyball Spiking Actions Performed in the Turning Point Core Trainer.

Variable	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
SH_{SA} (°)										
M	-47.21	-49.36	-48.93	-48.71	-49.93	-49.86	-52.50	-51.93	-53.07	-49.93
SD	-16.26	-15.97	-15.00	-11.57	-11.78	-14.21	-15.71	-15.91	-16.24	-14.34
S_{AV} (°·s^{-1})										
M	392.86	378.57	378.57	400.00	421.43	400.00	400.00	407.14	385.71	400.00
SD	47.46	42.58	57.89	67.93	57.89	67.93	55.47	47.46	66.30	67.93
H_{AV} (°·s^{-1})										
M	235.71	250.00	242.86	242.86	264.29	264.29	257.14	242.86	257.14	235.71
SD	84.19	51.89	85.16	64.62	63.33	63.33	64.62	75.59	85.16	63.33

Table-3. Means, Standard Deviations, Ranges, Cronbach's Alpha (a), 95% Confident Interval, and Standard Error of Measurement for SH_{SA}, S_{AV}, and H_{AV} During Volleyball Spiking Actions Performed with the Turning Point Core Trainer.

Variable	*M* ± *SD*	Range	a	95% CI	SEM
SH_{SA} (°)	-50.14 ± -13.23	-19.9 to -67.3	a =.98	a =.96 - .99	-1.94
S_{AV} (°-s^{-1})	396.43 ± 41.51	300 to 470	a =.91	a =.81 - .96	13.28
H_{AV} (°-s^{-1})	249.29 ± 57.44	120 to 340	a =.94	a =.88 - .98	13.95

Note. Gender: female, *n* = 14.

Table-4. F-statistics, p-Value Significance, and Ranges of the 10 Trials for SH_{SA}, S_{AV}, and H_{AV} During Volleyball Spiking Actions Performed in the TP Device

Variable	*F*-statistic	*p*-value	Range
SH_{SA}	1.270	.261	-47.21 to - 53.07
S_{AV}	1.380	.205	378.57 to 421.43
H_{AV}	.858	.564	235.71 to 264.29

Note. Gender: female, *n* = 14.

4. DISCUSSION

The primary aim of this study was to establish preliminary evidence relative to the internal consistency, as determined by Cronbach's alpha, for the TP as a measure of SH_{SA}, S_{AV}, and H_{AV} in female collegiate volleyball athletes. It was hypothesized that the TP would have high internal consistency reliability coefficients as measures of SH_{SA}, S_{AV}, and H_{AV} in female collegiate volleyball athletes and the study results support the hypothesis. The Cronbach's alpha coefficients across the 10 SH_{SA}, S_{AV}, and H_{AV} trials were a = .98, a = .91, a = .94, respectively, indicating excellent internal consistency reliability (DeVellis, 1991; Bruton *et al.*, 2000).

Another approach to examining the reliability of the TP measurements is to determine precision or repeatability. Precision is influenced by measurement error and can be analyzed by examining the SEM or percent error for the each variable or as a CV (Barker *et al.*, 2006). The former is an absolute measure of reliability and is expressed in the actual unit of measurement-degree/milliseconds (d/ms); the latter is a measure of relative reliability and in this case is expressed as a percentage score (Bruton *et al.*, 2000). Between subject variation was used to calculate SEM, along with the intrasubject or within subject CV (Aragon-Vargas, 2000).

The SEM result across the 10 SH_{SA}, S_{AV}, and H_{AV} trials were generally small, SEM = -1.94 degrees, 13.28 degrees/s, 13.95 degrees/s, respectively, indicating excellent measurement precision (Bruton *et al.*, 2000). However, a review of the intrasubject error or within subject CV and between subject CV shows high error variability in the H_{AV} (0.00-33.33%; 15.61%), followed by the SH_{SA} (6.42-25.15%; 12.03%), and H_{AV} (0.00-15.79%; 8.78%), indicating larger variability for within subject and lower for between subject (Bruton *et al.*, 2000). The higher percent error for within subject CV found in this study may be a reflection of the difficulty for volleyball players to mimic volleyball spikes using the TP. For example, the volleyball spike in the sport of volleyball normally involves a 3-4 step approach followed by a vertical jump, whereas in the TP, the volleyball spiking actions are performed from a standing position, which may generate responses that vary a little from trial-to-trial in the study. The stability of the 10 SH_{SA}, S_{AV}, and H_{AV} trials in the TP was determined by using a two-way mixed factor (participants random and trials fixed) repeated measures factorial ANOVA. The ANOVA results indicated that the mean values for the 10 trials were stable and not statistically different from one another (F = 1.27, p = .261; F = 1.38, p = .205; F = .858, p = .564), respectively.

4.1. Limitations

We acknowledge some limitations of the current study. First, there are two different types of reliability evidence that can be established for the TP, internal consistency reliability and test-retest reliability (Kaplan and Saccuzzo, 2008). The results of this study are limited and provide only internal consistency reliability evidence for the TP as a measure of SH_{SA}, S_{AV}, and H_{AV}, because it was not feasible to bring the participants back to test them again in the TP, due to their commitments with practice and academic work. Another limitation was the lack of an approach. The volleyball spike normally involves a 3-4 step approach followed by a vertical jump, whereas in the TP, volleyball spiking actions are performed from a standing position, which may affect the results of the study. Another limitation is that all participants in the current study were female Division 1 volleyball athletes from the University of Utah, which may decrease generalizability. Therefore, the results of the current study cannot be generalized to other populations, such as elite or international female volleyball athletes and/or male volleyball players.

A final limitation of the current study is that the TP method has a lower firing frequency in providing and detecting small changes in velocity (degree/s) for S_{AV} and H_{AV} during volleyball spiking actions. This may interfere with the results of the study and increase the error variance for both SEM and CV.

5. CONCLUSIONS AND RECOMMENDATIONS

This study was the first to examine the internal consistency reliability coefficient for the TP as a measure of SH_{SA}, S_{AV}, and H_{AV}. These results support the reliability of the TP and indicate a high internal consistency reliability coefficient as determined by Cronbach's alpha across the 10 trials for each variable. Future research, should examine the test-retest reliability coefficient for the TP as a measure of SH_{SA}, S_{AV}, and H_{AV} to assess random variation over time (across different days). Because the internal consistency reliability coefficient results in the current study can only be generalized for female Division I volleyball athletes, we recommend that future studies recruit volleyball players from different levels, such as elite or international volleyball athletes and/or male volleyball players.

5.1. Applications of the TP

Coaches and volleyball players may use the TP as a method to measure SH_{SA}, S_{AV}, and H_{AV} but should be aware that further reliability evidence and more specifically test-retest reliability is needed to ensure the ability of the device to produce consistent scores over time. The current study suggests that the TP may be used as a training method to test and monitor the effect of training programs that involve the rotational variables for the purpose of enhancing volleyball performance during volleyball spikes.

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