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ORIGINAL RESEARCH

SPORTSMETRICS™ TRAINING IMPROVES POWER AND LANDING IN HIGH SCHOOL ROWERS

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ABSTRACT

Background: Successful rowing participation requires leg power, back strength, cardiovascular endurance, and balance. SportsMetrics™ training improves lower limb alignment, hamstring peak torque, and vertical jump height; however, this training has not been used in athletes who row and may have different outcomes based on experience level.

Purpose/Hypotheses: The purpose of this study was to compare the effects of a six-week SportsMetrics™ training program on vertical jump height (VJH), Y Balance Test (YBT), and Drop Jump Screening Test (DJST) between novice and varsity high school rowers. The authors hypothesized that following Sportsmetrics™ training; novice rowers would not be different from varsity rowers in VJH and YBT. All rowers will have improved normalized knee joint separation distance in DJST following training.

Study Design: Cross sectional.

Methods: 52 (31 varsity: 16.4 ± 0.8 years, 62.0 ± 9.0 kg, 1.7 ± 0.1m [mean ± SD], 21 novice: 14.5 ± 0.7years, 58.6 ± 5.4 kg, 1.7 ± 0.1m [mean ± SD]) high school rowers completed the Sportsmetrics™ training and participated in the study. Varsity rowers were defined as a returner; any new rower was considered novice. Differences in age, weight, and height were examined using independent t-tests. Repeated measures ANOVA assessed pre- to post-training differences between groups in VJH, YBT composite score (CS) and reach asymmetry (ASY), and normalized knee joint separation distance (DJST).

Results: VJH significantly improved for all athletes from pre- to post-training (mean ± SD: 29.0 ± 7.0 vs. 31.9 ± 5.1cm; $p = 0.001$) and normalized knee separation distance significantly increased for all athletes pre to post training at the pre-landing (mean ± SD: 58.2 ± 12.5 vs. 68.7 ± 7.4%; $p < 0.001$), landing (mean ± SD: 49.4 ± 18.2 vs. 66.3 ± 14.2%; $p < 0.001$), and take off (mean ± SD: 47.8 ± 18.4 vs. 64.8 ± 13.8%; $p < 0.001$) phases of the jump; there was no effect for group. There was no difference in varsity and novice pre to post training in YBT CS (99.3 ± 7.5 vs. 99.7 ± 7.1%; $p = 0.53$) or ANT ASY (mean ± SD: 3.4 ± 4.6 vs. 2.7 ± 2.3; $p = 0.36$).

Conclusions: SportsMetrics™ training improved VJH regardless of experience level; which suggests that rowers may have more leg power following training. Normalized knee joint separation distance increased to greater than 60% of hip joint separation distance following training, indicating that training reduced serious knee injury risk.

Level of Evidence: Level 3

Keywords: Drop Jump Screening Test, Rowing, Sportsmetrics™, Vertical Jump Height, Y-Balance Test

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INTRODUCTION

In order to be successful in the sport of rowing it is vital that athletes have substantial leg power,[1] back strength,[2] cardiovascular endurance,[3] and balance.[4] Not only do these characteristics dictate the success of the rower, but they often differ based on level of rowing participation, (varsity or novice) and years of sport experience. Varsity rowers have greater vertical jump heights compared to rowers with zero years of rowing experience; additionally, varsity rowers and rowers with three years of rowing experience have faster two kilometer row times on a rowing ergometer compared to rowers with zero years of rowing experience.[5] Also, non-elite rowers with greater leg strength generated greater leg extension power compared to non-elite rowers with lower strength.[6] The demonstrated differences between rowers of different levels of experience, as well as compared to control participants, suggests that training experience impacts leg power and rowing performance. The authors of a recent review suggest that explosive power exercises may be beneficial during the competitive phase of training for rowing athletes to achieve peak sport performance.[7] One way to address explosive power is through plyometric training, which includes exercises of varying intensities that focus on eccentric contractions immediately followed by explosive concentric contractions. Plyometric training utilizes the stretch shortening principle, with a short amortization phase, to gain explosive power.[8] There are a variety of plyometric exercises that target both upper and lower extremity power, one such pre-packaged plyometric exercise regimen is the Sportsmetrics™ training program.

Sportsmetrics™ is a proprietary training program consisting of progressive plyometric exercise that has been documented to improve vertical jump height,[9] agility and dynamic balance,[10] and landing kinematics.[11] Vertical jump height[9] and single leg triple crossover hop,[10] both measures of leg power, have been documented to increase by at least 1cm and 36cm, respectively, after six weeks of plyometric training in athletes in a variety of sports. Knee joint separation distance, which has been suggested to represent dynamic knee valgus, is measured using the Drop Jump Screening Test.[11] Knee joint separation distance also improves following Sportsmetrics™ training with research suggesting that athletes with normalized knee joint separation distance of greater than 60% of hip joint separation distance are at a decreased risk for ACL injury.[11] This may suggest that theoretically, following Sportsmetrics™ training, core stability may be improved as core muscle weakness and decreased endurance may contribute to dynamic knee valgus during repetitive jumping.[12]

Dynamic balance has been suggested as a measure of core function[13] and core stability, which is important for injury prevention.[14] The Y-Balance Test (YBT) is one way to measure dynamic balance. The YBT has two outcomes commonly reported after its administration. One is a composite score that is created by summing the maximum reach distances and normalizing to the individuals' leg length. The second is a measure of reach asymmetry, which is the absolute difference in the maximum right to left reach distance for each of the three reach directions, anterior, posteromedial, and posterolateral. In one study, YBT anterior reach asymmetry was associated with an increased noncontact and overuse injury risk across a diverse Division I sample of collegiate athletes[15] and reduced composite score has been associated with noncontact injuries in collegiate football.[16] In female high school[17] athletes both increased anterior reach asymmetry and reduced composite score were associated with noncontact injury. However, the composite score associated with an increased risk of injury was different between these two participant samples. Further, research suggests that exercises that enhance core function improve dynamic balance performance;[13] however, the effect that Sportsmetrics™ training may have on dynamic balance has yet to be established.

Therefore, the purpose of this study was to compare the effects of a six-week SportsMetrics™ training program on vertical jump height (VJH), Y Balance Test (YBT), and Drop Jump Screening Test (DJST) between novice and varsity high school rowers. The first hypothesis was that following Sportsmetrics™ training, novice rowers would not be different from varsity rowers in VJH and YBT (composite score and anterior reach asymmetry). The second hypothesis was that all rowers would have improved normalized knee joint separation distance in DJST following training.

METHODS

Study Design

This study was a cross sectional study with the independent variable being level of high school rowing (varsity – returning rower; novice – new rower) and the dependent variables of vertical jump height (VJH), Y Balance Test Composite Score (YBT CS), Y Balance Test Anterior Reach Asymmetry (YBT ANT ASY), and normalized knee joint separation distance during the pre-landing, landing, and take off phase of the Drop Jump Screening Test (DJST).

Participants

All participants were female varsity (n = 31) or novice (n = 21) rowers from a single high school rowing team who completed a Sportsmetrics™ training program under the direction of a physical therapist certified in Sportsmetrics™ as part of their normal training program during the pre-season. As a result this research was classified as Exempt Research by the institutional review boards at both Daemen College and Catholic Health System. Any rower who was not in attendance for more than two training sessions was removed from the analysis of the data. Fifty-eight rowers started the Sportmetrics™ training program; however, seven were not included in data analysis due to not completing the training program or quitting the team.

Sportsmetrics™ Training Program

A general Sportsmetrics™ training program (Table 1) was performed two times per week for six weeks. Prior to each training session participants performed the suggested dynamic warm consisting of the following exercises: heel/toe walk, straight leg walk, hand walk (walking out on hands while keeping feet planted on ground), forward lunge, backward lunge, leg cradle walk (walking while alternating picking up one leg with hip flexion and external rotation), dog and bush walk (walking while alternating legs in hip flexion, then internal rotation, and hip extension). All training sessions took place on a basketball court.

Vertical Jump Height

Vertical Jump Height (VJH) was performed using a countermovement jump. A tape measure was fixed to the wall. Prior to performance of VJH the participant stood against the wall and extended their arm up as far as possible above their head. This was used as the standing height. Participants were given a small piece of tape to place on the wall as close to the measurement tape as possible during the VJH performance to mark the maximum height at which they jumped. VJH was then determined by taking the difference between the maximum height at which they jumped and the standing height. All participants completed three VJHs and the maximum of the three was used for comparison.

Y Balance Test

The Y Balance Test (YBT) was administered by an individual certified in YBT administration.[18] Prior to performing the YBT all participants watched a video[19] as this has been suggested to be helpful with the learning curve associated with test performance. All participants were given four to six practice trials in each anterior (ANT), posteromedial (PM), and posterolateral (PL) reach directions as this has also been demonstrated to allow for learning to plateau.[20] After the practice trials leg length was measured from the ASIS to the distal tip of the medial malleolus on the right limb. Participants then maintained single leg balance on the right and left lower extremity while the contralateral limb reached in the ANT, PM, and PL directions (Figure 1). Three successful reaches were performed for each reach direction; the maximum reach distance in each direction was used for data analysis. Anterior Reach Asymmetry (ANT ASY) was calculated by the absolute difference between right and left extremities reach distance in ANT direction and expressed in centimeters. YBT CS was determined by summing the average of the maximum right and left reach distances in each direction, dividing by three times leg length, and multiplying by 100 to obtain a percentage.

$$\text{ANT ASY} = \left| \text{MAX RANT} - \text{MAX LANT} \right|$$

$$\text{CS} = [(\text{RANT} + \text{LANT}/2) + (\text{RPM} + \text{LPM}/2) + (\text{RPL} + \text{LPL}/2)/3 * \text{LL}] * 100$$

Drop Jump Screening Test

The Drop Jump Screening Test (DJST) was performed as originally described by Noyes et al[11] such that participants performed a drop jump from a 30cm height box and immediately upon landing participants were instructed to perform a maximal vertical jump (Figure 2). Participants were outfitted with reflective markers placed on right and left greater trochanter, right and left lateral malleolus, and the center of the right and left patella. The DJST

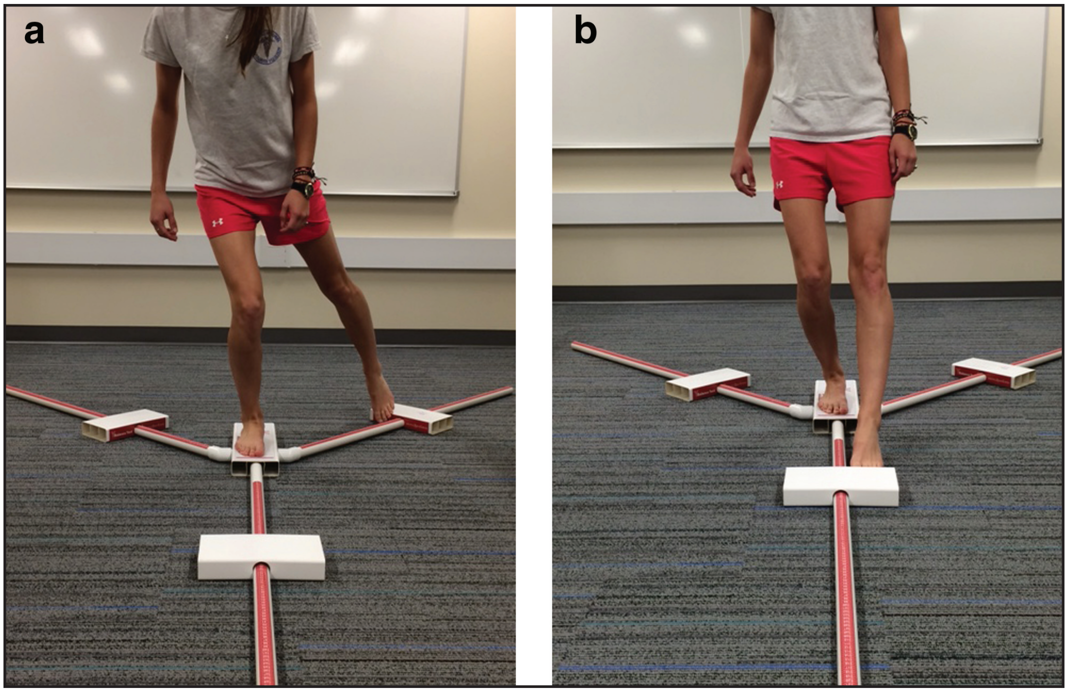

Figure 1. *The Y-Balance Test. a. Posteromedial Reach b. Anterior Reach*

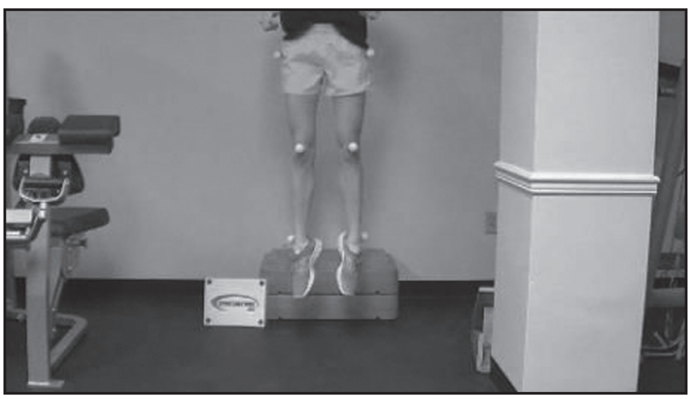

Figure 2. *Images of the Drop Jump Screening Test. Participants drop off of the box and upon landing on the ground they are asked to immediately explode up in to a vertical jump. Image is at max height of vertical jump.*

was demonstrated for all participants prior to completing three successful jumps.

A SONY HDR-CX190 video camera was placed directly in front of the box at a distance of 366cm (12 feet) from the front of the box and the Sportsmetrics™ Calibrating Placard was placed next to the front edge of the box. The video camera recorded the DJST for offline digitizing and analysis using the Valgus Digitizer Software (Sportsmetrics™ Software for Analysis of Jumping Mechanics, Cincinnati, OH) to assess normalized knee joint separation distance (%) at three digitized points: pre-landing (point at which toes initially make contact with ground), landing (deepest point in the landing on the ground), and take off (point at which there is initial forward and upward movement of arms and body) of the video that demonstrated the participants best jumping ability. The retroreflective markers on the right and left greater trochanters and left and right patellas were used to determine hip joint separation and knee joint separation, respectively, in centimeters (cm), at each of the digitized landing points. Normalized knee joint separation distance was calculated as the percentage of the knee joint distance measurement (in cm) to the hip joint distance measurement (in cm). The hip joint separation distance measurement was used to normalize the knee joint separation distance measurement because the distance between the hip markers remains unchanged during each phase of the DJST. Normalized knee joint separation distance percentages below 60% of hip joint separation distance indicates that an athlete may be at higher risk for a serious knee injury.

Procedures

All high school female rowers took part in a six-week Sportsmetrics™ training program (Table 1) during pre-season of the 2014 spring rowing season. Prior

Table 1. *Sportsmetrics™ Training Program*

	Jumps	Sets	Repetitions	
			Week 1	**Week 2**
Technique Development (Weeks 1 & 2)	Wall Jumps	3	20sec	25sec
	Tuck Jumps	3	20sec	25sec
	Squat Jumps	3	10sec	15sec
	Barrier Jumps (S/S)	3	20sec	25sec
	Barrier Jumps (F/B)	3	20sec	25sec
	180º Jumps	3	20sec	25sec
	Broad Jumps	3	5 rep	10 rep
	Bounding in Place	3	20sec	25sec
			Week 3	**Week 4**
Fundamentals (Weeks 3 & 4)	Wall Jumps	3	25sec	30sec
	Tuck Jumps	3	25sec	30sec
	Jump, Jump, Jump Vertical	3	5 rep	8 rep
	Squat Jumps	3	15sec	20sec
	Barrier Jumps (S/S)	3	25sec	30sec
	Barrier Jumps (F/B)	3	25sec	30sec
	Scissor Jumps	3	25sec	30sec
	Single Leg Hops (stick)	3	5 rep	5 rep
	Bounding for Distance	3	1 run	2 run
			Week 5	**Week 6**
Performance (Weeks 5 & 6)	Wall Jumps	3	20sec	20sec
	Up Down 180 Vertical	3	5 rep	10 rep
	Squat Jumps	3	25sec	25sec
	Mattress Jumps (S/S)	3	30sec	30sec
	Mattress Jumps (F/B)	3	30sec	30sec
	Hop, Hop, Hop Stick	3	5 rep	5 rep
	Jump into Bounding	3	3 run	3 run

Sec= number of seconds for one set; Rep= number of repetitions for one set; run=the length of the basketball court; S/S= represents side to side; F/B= front to back

to participation in the training program an initial assessment of VJH, YBT, and DJST was performed using the protocols previously described. All six weeks of training were overseen by a licensed physical therapist and/or a certified athletic trainer to ensure accuracy of exercises and to provide corrective feedback when necessary. Within one week of the conclusion of the training program all rowers had a post training assessment of VJH, YBT, and DJST using the same methods as the initial assessment.

Statistical Analysis

Data were assessed for skewness and kurtosis via histograms. Levene's Test was used to assess error variances. Independent t-tests were used to determine differences in age, weight, and height between varsity and novice rowers. For normally distributed data with equal error variances, repeated measures ANOVAs were used to assess differences pre- to post-training and between groups in VJH, YBT CS, YBT ANT reach asymmetry, and normalized knee joint separation distance (DJST) at pre-landing, landing, and take off. In the case of non-normally distributed data or lack of equal error variances, non-parametric analyses consisted of Mann Whitney U to assess differences between groups during both pre- and post-training, while a Wilcoxon Sign Rank test was used to assess differences from pre to post training. Intraclass Correlation Coefficients were calculated to assess the Standard Error of the Measurement (SEM) [SEM = SD√1-SEM)] for VJH; SEM was calculated using the average SD from the pre and post-training VJH. An alpha level of < 0.05 was used to indicate statistical significance. All statistical analysis was performed using IBM SPSS version 23 (IBM, Armonk, NY).

RESULTS

Analysis of histograms for pre and post VJH, knee joint separation distance, YBT CS, and ANT AYS demonstrated normal distribution across both groups. Further, Levene's Test for equality of error variances was not significant for VJH (pre-training: $p = 0.05$; post-training: $p = 0.60$), knee joint separation distance during pre-landing (pre-training: $p = 0.12$; post-training = 0.90) and take off (pre-training: $p = 0.07$; post-training: $p = 0.08$), YBT CS (pre-training: $p = 0.35$; post-training: $p = 0.75$), and ANT ASY (pre-training: $p = 0.21$; post-training: $p = 0.48$). However, there were unequal

Table 2. *Demographic and anthropometric means ± standard deviations for varsity and novice high school rowers*

	Age (years ± SD)	Weight (kg ± SD)	Height (m ± SD)
Varsity Rowers	16.4 ± 0.8	62.0 ± 9.0	1.7 ± 0.1
Novice Rowers	14.5 ± 0.7	58.6 ± 5.4	1.7 ± 0.1
All Rowers	15.6 ± 1.2	60.7 ± 7.9	1.7 ± 0.1
p-value	<0.0001*	0.14	0.37

* denotes statistically significant difference between varsity and novice rowers

error variances in normalized knee joint separation distance during landing (pre-training: p = 0.03; post-training: p = 0.04). Varsity rowers were significantly older than novice rowers; however, weight and height were the same between groups (Table 2). There was a main effect for VJH such that it significantly improved in both groups pre to post training (SEM 3.55cm); there was no effect for group (Table 3). There was also a main effect for knee joint separation distance such that it significantly increased in both groups pre to post training at the pre-landing and take-off phases of the jump; however, there was no effect for group (Figure 3). There was no difference between pre- to post-training YBT CS or ANT ASY in either varsity or novice rowers (Table 3). Although 52 of 58 rowers completed the six-week Sportsmetrics™ training, some rowers were not available for the post testing sessions; therefore, the vertical jump height comparison represents data from 49 participants (31 varsity and 18 novice), the YBT comparisons represents data from 44 participants (23 varsity and 21 novice), and the knee joint separation distance comparisons represents data from 51 participants (31 varsity and 20 novice).

DISCUSSION

The purpose of this study was to compare the effects of a six-week SportsMetrics™ training program on vertical jump height (VJH), Y Balance Test (YBT), and Drop Jump Screening Test (DJST) between novice and varsity high school rowers. All participants improved vertical jump height and landing position following six weeks of Sportsmetrics™ training.

Table 3. *Pre- and post-training means ± standard deviations for varsity and novice high school rowers in vertical jump (VJH), Y Balance Test Composite Score (YBT CS) and Y Balance Test anterior reach asymmetry (ANT ASY).*

	VJH Pre (cm)	VJH Post (cm)	YBT CS Pre (%LL)	YBT CS Post (%LL)	ANT ASY Pre (cm)	ANT ASY Post (cm)
Varsity Rowers Mean±SD	29.9±7.8	32.1±4.9	99.4±6.8	99.3±7.0	2.6±1.8	2.6±2.5
Novice Rowers Mean±SD	27.3±5.2	31.5±5.6	99.2±8.3	100.0±7.3	4.3±6.3	2.8±2.3
All Rowers Mean±SD	29.0±7.0	31.9±5.1	99.3±7.5	99.7±7.1	3.4±4.6	2.7±2.3
p-value (group x time)		0.29		0.43		0.38
p-value (main effect)		0.001*		0.53		0.36

* denotes statistically significant main effect for time (significant change from pre to post training regardless of level of rower)

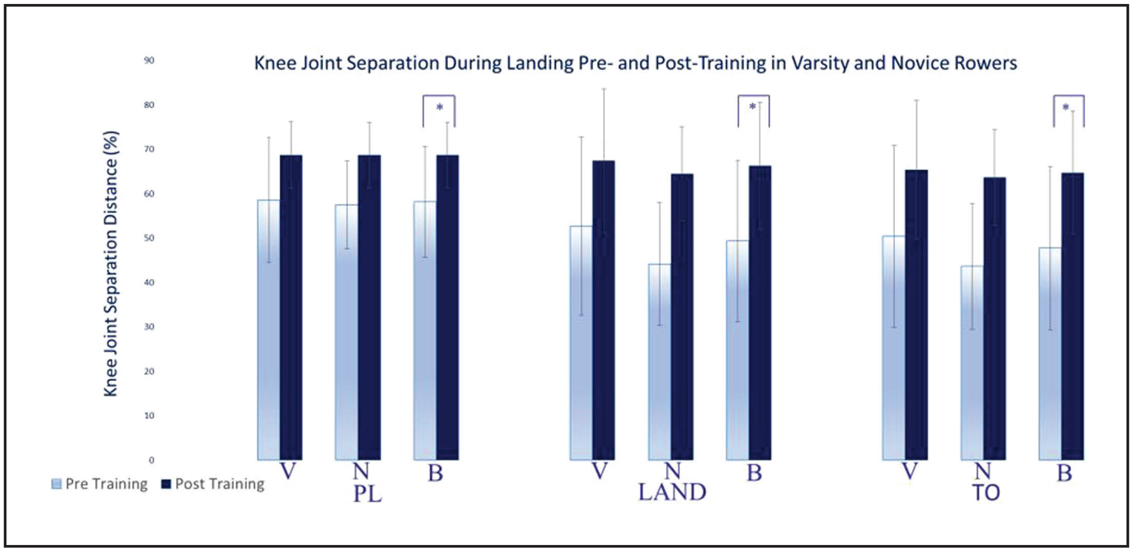

Figure 3. *Pre- and post-training means ± standard deviations for varsity (V), novice (N), and both groups (B) in normalized knee separation distance (%) during pre-landing (PL), landing (LAND), and take off (TO) phases of the Drop Jump Screening Test. Normalized knee joint separation distance represents the percentage of the knee separation measurements (cm) relative to the hip separation measurement (cm). * = p < 0.001*

The first hypothesis was that following Sportsmetrics™ training, novice rowers would not be different from varsity rowers in VJH and YBT; however, all rowers had significant improvements in vertical jump height with varsity rowers improving by approximately 2cm and novice increasing by approximately 4cm. Although not statistically significant, novice rowers, clinically speaking, had an increase equal to double that of the varsity rowers. A lack of statistically significant differences between groups may have resulted from a Type II statistical error ($\beta = 0.82$), which could have been due to a small sample size. These changes in vertical jump height across both groups could be considered clinically relevant as others have reported significant improvements in vertical jump height of only a 1cm after Sportsmetrics™ training;[9] however, one should use caution with the interpretation of the current data as the SEM was 3.55cm. The large increase in the novice rowers in this study may have been due to neural changes as jump training was likely a novel task for this type and level of athlete; it is possible that participants improved their ability to perform the task via a feed forward motor control strategy.[21] Perhaps Sportsmetrics™ training induces changes to the feed forward motor control strategies utilized during landing preparation, which has been demonstrated following plyometric training in other research,[22] as a means for knee ligament injury prevention reported in the literature.[23]

To date the literature has not directly evaluated the effects of the Sportsmetrics™ program on dynamic balance, but research suggests that neuromuscular training, similar to that utilized in Sportsmetrics™, improves postural[24] and dynamic[25] stability. The use of hold positions during deceleration movements, similar to those used in the Sportsmetrics™ training, has been considered to be a functional balance or single-leg core stability training strategy.[26] Core strength has been suggested to be integral to balance[27] and physioball training focused on back and abdominal exercises (i.e. curl up and back extension) improved abdominal and erector spinae muscle activity and static balance times.[28] Therefore, if there are changes in core stability following jump training it is possible that this could enhance dynamic balance. These findings did not support the hypothesis because YBT performance did not induce statistically significant changes in composite score or anterior reach asymmetry in novice rowers, and novice rowers were not different from varsity rowers. However, it is important to note that the novice rowers had an average anterior reach asymmetry of 4.3cm pre training and this was reduced to 2.8cm post training. Other studies[15,17] suggest that reach distance difference greater than 4cm indicates asymmetry between right and left limbs. Clinically speaking, the anterior reach asymmetry demonstrated by novice rowers post training was similar to varsity rowers who demonstrated a mean of 2.6cm anterior reach asymmetry. More importantly, following Sportsmetrics™ training novice rowers reduced their anterior reach asymmetry to be below the threshold (4cm) known to be associated with an increased risk of noncontact and overuse lower extremity injury.[15,17]

Authors of a recent review of rowing injuries[29] and a prospective cohort study of rowing injuries[30] suggests that knee injuries are predominant along with low back injury. These injuries reported by Hosea and Hanafin[29] and Wilson et al[30] are primarily overuse in nature. Smith et al[15] showed a significant association with increased YBT anterior reach asymmetry and lower extremity noncontact and overuse injuries in collegiate athletes. Further, individuals with patellofemoral pain syndrome perform worse on the Star Excursion Balance Test (SEBT).[31] Additionally, a reduction in asymmetry in novice rowers may improve rowing performance as asymmetry of the lower extremities during the task of rowing causes wiggle in the boat, which will slow forward progress.[32] The current findings, as well previous literature, suggest that improvement in lower extremity asymmetry in novice rowers may be of particular importance as it may reduce the risk of overuse injuries as well as improve rowing performance while in the boat.

The second hypothesis was supported in that all rowers increased normalized knee joint separation distance in DJST following training in all three phases of landing: pre landing, landing, and take off. The findings of this current study are also supported in the literature across various populations engaged in Sportsmetrics™;[9,33] however, this is the first study to document improved lower limb alignment at landing in rowers. Improved lower limb alignment at landing may reduce the risk for patellofemoral pain syndrome (PFPS) in rowers as increased knee abduction angle is one of several strong predictors of PFPS.[34] Additionally, it has been suggested that improvement of frontal plane knee mechanics should be incorporated into PFPS injury prevention programs;[35] thus Sportsmetrics™ could be incorporated into training programs for rowers to attempt to decrease the incidence of PFPS.

The average normalized knee joint separation distance improved to be greater than 60% of the hip separation distance in all three phases of landing for both novice and varsity rowers following training. This is important as less than 60% of normalized knee joint separation distance relative to hip joint separation represents dynamic knee valgus, which has been suggested to put athletes at risk for non-contact knee injury.[11] Additionally, given the nature of the sport of rowing there is tremendous load to the patellofemoral joint, which can result a variety of overusing injuries including in PFP[29] and patellar tendonitis.[30] Therefore, improving dynamic knee alignment may reduce the incidence[34] of lower extremity overuse injuries like PFP in rowers.

While this is the first study to assess the effects of Sportsmetrics™ training in rowing athletes, there are some limitations. First, the participants only took part in the training sessions two times per week rather than the suggested three times per week. This was based on training availability of the team; however, more substantial findings may have been present, particularly in the measurement of dynamic balance, had the training taken the recommended three times weekly. Additionally, the design of this study was pre-test post-test, but rather than a randomized control trial a cross sectional design was utilized to study a cohort of rowing athletes. This design limits the true cause and effect nature of the study as all participants completed their regularly scheduled training activities in addition to the Sportsmetrics™ training. However, it is important to note that there were improvements in all subjects in power and knee separation distance following the six weeks of training. It is likely, given the nature of normal training for the sport of rowing and past research using Sportsmetrics™, that normalized knee joint separation distance differences seen post training were directly attributable to Sportsmetrics™ and improvement in vertical jump was influenced by Sportsmetrics™.

CONCLUSION

SportsMetrics™ training improved vertical jump height regardless of experience level; suggesting rowers may have more leg power following training. YBT was not affected by training. Following training drop jump knee separation increased to greater than 60%; indicating training reduced serious knee injury risk. Future researchers should consider evaluating the cause and effect nature of Sportsmetrics™ training on athletes who row through implementation of a randomized control trial.

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