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STRENGTH AND POWER CHARACTERISTICS OF ELITE SOUTH AFRICAN BEACH VOLLEYBALL PLAYERS

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ABSTRACT

This study investigated the strength and power characteristics of 13 elite South African male beach volleyball players. The results indicate that elite beach volleyball players have a mean stature of 185.28 cm (∀7.2), mean mass of 82.01 kg (∀9.7) and percentage body fat of 13.12% (∀2.4). Mean isokinetic peak torque values (Nm) for leg extension at 60 degrees $\cdot s^{-1}$=268.03, 180 degrees $\cdot s^{-1}$=188.53, and 240 degrees $\cdot s^{-1}$=162.61; leg flexion at 60 degrees $\cdot s^{-1}$=152.65, 180 degrees $\cdot s^{-1}$=117.65 and 240 degrees $\cdot s^{-1}$=104.61. Mean isokinetic peak torque values for leg extension relative to body mass ($Nm \cdot kg^{-1}$) were for extension at 60 degrees $\cdot s^{-1}$=3.29, 180 degrees $\cdot s^{-1}$=2.37, and 240 degrees $\cdot s^{-1}$=2.0 and flexion at 60 degrees $\cdot s^{-1}$=1.86, 180 degrees $\cdot s^{-1}$=1.45 and 240 degrees $\cdot s^{-1}$=1.29. Vertical jump performance (VJP) was evidenced by an average of 61.73 cm (∀4.5). The results suggest that elite beach volleyball players have relatively strong legs when compared with studies that assessed sportsmen using isokinetic devices at the same testing speeds. VJP was however modest when compared to previous studies of elite indoor volleyball players.

Keywords: Beach volleyball; Strength; Isokinetic; Power; Vertical jump performance.

INTRODUCTION

Indoor Volleyball (6-a-side) has been described by Künstlinger *et al*. (1987) as an interval sport with short periods of high intensity alternating with resting periods. Research by Davies *et al*. (1998) on the temporal components of beach volleyball at the World Championships in 1995, also identified it as an intermittent activity, with rally phases averaging 5.39 seconds and rest phases averaging 19.08 seconds.

Davies (2000) indicated that for any given comparable sequence of physical activity performed by an indoor volleyball player, the same sequence on sand would be more strenuous. This is because locomotion on sand increases energy cost by unit distance approximately 1.8 times when walking, and 1.2 times when running (Zamparo *et al*., 1992; Davies, 1999a).

Bearing in mind that sand increases the metabolic cost of locomotion, and slows the player around the court, as well as reducing jump performance (Davies, 1999a; Davies 1999b). It is apparent that in spite of the detrimental effects of sand on human performance, elite players will nevertheless attempt to play the game of beach volleyball as effectively as possible. One should also note that beach volleyball is a 2-a-side game on a court the same size as an indoor court with the same height of net. Given the unique effects of sand on performance and the desire by elite players to run and jump as dynamically as possible, it may well be the case that prolonged exposure to the effects of sand on human performance may have seen some unique biological adaptations. This might be most clearly seen in improvements in strength and power of the legs to overcome the compliant nature of sand and its detrimental effects on performance.

Thus it may be of interest therefore to see whether or not, players who regularly participate in elite beach volleyball on a compliant substrate such as sand have developed unique physical adaptations, including comparatively high leg strength and power.

METHODS

Subjects

Thirteen (n=13) male elite South African beach volleyball players, who were at the time of testing ranked in the top 20 seedings list of the Beach Volleyball Council (BVC) volunteered. Prior to their participation in the study, all subjects were required to read and sign an informed consent form. All subjects were given the opportunity to ask questions or withdraw from a test if they so wished.

Anthropometric measures

The anthropometric measures of stature and mass were done in accordance to the directives indicated in the Anthropometric Standardization Manual (Lohman *et al*., 1988). Percentage body fat was calculated using the Siri equation as cited by Durnin and Womersley (1974) from skinfold measures of four sites, namely biceps, triceps, supra iliac and subscapular.

Isokinetic dynamometry

Prior to testing, the subject was informed about the purpose and procedures of the test and, in lay terms the functioning of the isokinetic mechanism. This was followed by a warm-up involving five minutes of cycling at a work load of 125 watts, followed by stretching of the major muscle groups of the legs. Isokinetic knee extension/flexion test at three angular velocities, namely 60, 180 and 240 degrees $\cdot s^{-1}$ were applied according to guidelines for standardized isokinetic protocol in clinical usage (Davies, 1987). The test was performed using one of three devices, depending upon location, namely; an Acron Computerized Isokinetic Dynamometer (Therapy Products – Suffolk, England), Cybex II or a Cybex Norm (Division of Lumex, 2100 Smithtown Avenue, Ronkonkoma, New York 11779, USA).

Power-vertical jump performance

The subjects followed a warm-up routine, which included jogging and stretching, followed by submaximal two-legged jumps with preparatory counter arm movement. After dipping the fingertips of their dominant hand into the chalk powder the subjects-reach-height was determined: standing sideways against the board with both feet on the ground and heels together, the subject reached as high as possible and made a mark on the board. To execute the jump, the knees were bent and then in a vertical maximal effort the subject jumped making a mark against the board with the hand of the outstretched arm at the highest point reached. Subjects were allowed to swing their arms in preparation for the jump but were not permitted to move their feet. The difference between the reach-height and jump-height was then measured to the nearest centimetre. After watching a demonstration of the test, subjects were allowed to perform three maximal jumps following in close succession.

Statistical procedures

Statistical analysis was performed with the Statsgraphics software package, Version 5 (1991). Summary statistical analysis included means and standard deviations, along with One-Way Analysis of Variance (ANOVA) two tailed at $p<0.05$.

RESULTS

Stature, mass and percentage body fat

The present study indicates that the 13 elite South African beach volleyball players measured had an average stature of 185.28 cm, mass of 82.0 kg and percentage body fat of 13.12%. These values are presented in Table 1.

TABLE 1. **MEANS AND STANDARD DEVIATIONS FOR STATURE, MASS AND PERCENTAGE BODY FAT OF ELITE INDOOR AND BEACH VOLLEYBALL PLAYERS**

Stature (cm)	Mass (kg)	% Body Fat
185.28 (7.2)	82.0 (9.7)	13.12 (2.4)

Isokinetic evaluation of leg strength

The results of leg extension and flexion testing for left and right leg at three different speeds, namely 60, 180 and 240 degrees $\cdot$ s^{-1} in terms of peak torque and relative peak torque are shown in Tables 2 and 3 respectively, while bilateral differences are shown in Table 4, and quadricep/hamstring ratios are displayed in Table 5, 6 and 7.

TABLE 2. **PEAK TORQUE (NM) DURING LEG EXTENSION AND FLEXION AT 60, 180 AND 240 DEGREES $\cdot$ S^{-1}**

Leg	Extension			Flexion		
	60	180	240	60	180	240
Left	265.38 (35.66)	186.30 (34.71)	160.00 (37.92)	155.23 (34.75)	119.15 (30.04)	104.23 (30.26)
Right	270.69 (34.56)	190.76 (34.46)	165.23 (38.45)	150.07 (22.85)	116.38 (27.81)	105.00 (30.25)
Average	268.03	188.53	162.61	152.65	117.65	104.61

TABLE 3. **RELATIVE PEAK TORQUE (NM · KG^{-1}) DURING LEG EXTENSION AND FLEXION AT 60, 180 AND 240 DEGREES · S^{-1}**

Leg	**Extension**			**Flexion**		
	60	180	240	60	180	240
Left	3.24 (0.36)	2.28 (0.51)	1.97 (0.42)	1.89 (0.40)	1.49 (0.36)	1.29 (0.33)
Right	3.35 (0.36)	2.36 (0.39)	(2.04 (0.42)	1.84 (0.31)	1.41 (0.35)	1.30 (0.34)
Average	3.29	2.37	2.01	1.86	1.45	1.29

TABLE 4. **BILATERAL RATIOS (%) IN PEAK TORQUE PRODUCED AT 60, 180 AND 240 DEGREES · S^{-1}**

Leg	**Extension**			**Flexion**		
	60	180	240	60	180	240
Left	49.5	49.4	49.2	50.8	50.5	49.8
Right	50.5	50.6	50.8	49.2	49.5	50.2

TABLE 5. **PEAK ISOKINETIC KNEE EXTENSION/FLEXION TORQUE (NM) AND HAMSTRING/QUADRICEPS RATIO (%) AT 60 DEGREES · S^{-1}**

Leg	**Speed = 60 degrees · s^{-1}**		**Q/H ratio**
	Quadriceps	Hamstring	
Left	265.38 Nm	155.23 Nm	58.5%
Right	270.69 Nm	150.07 Nm	55.4%
Average	268.03 Nm	152.65 Nm	57.0%

TABLE 6. **PEAK ISOKINETIC KNEE EXTENSION/FLEXION TORQUE (NM) AND HAMSTRING/QUADRICEPS RATIO (%) AT 180 DEGREES · S^{-1}**

Leg	**Speed = 180 degrees · s^{-1}**		**Q/H ratio**
	Quadriceps	Hamstring	
Left	186.30 Nm	119.15 Nm	64.0%
Right	190.76 Nm	116.38 Nm	61.0%
Average	188.53 Nm	117.65 Nm	62.5%

TABLE 7. **PEAK ISOKINETIC KNEE EXTENSION/FLEXION TORQUE (NM) AND HAMSTRING/QUADRICEPS RATIO (%) AT 240 DEGREES · S^{-1}**

Leg	**Speed = 240 degrees · s^{-1}**		**Q/H ratio**
	Quadriceps	Hamstring	
Left	160.00 Nm	104.23 Nm	65.1%
Right	162.23 Nm	105.00 Nm	63.5%
Average	162.61 Nm	104.61 Nm	64.3%

Power-vertical jump performance (VJP)

The mean vertical jump performance (VJP) of the 13 elite male beach volleyball players was 61.73 cm that can be seen in Table 8. The mean values were also compared to vertical jump measures derived from national indoor volleyball players.

TABLE 8. **VERTICAL JUMP PERFORMANCE AND PERCENTAGE BODY FAT OF ELITE INDOOR AND BEACH VOLLEYBALL PLAYERS**

Group	VJP (cm)	% Body fat	Author(s)
USA	93.6 (6.1)	8.6 (0.5)	McGowen *et al*. (1990)
Canada National	93.0 (6.5)	6.3 (1.8)	Smith *et al*. (1992)
Japan	90.9 (---)		Toyoda (1974)
Canada Universiade	87.0 (5.5)		Smith *et al*. (1992)
England	75.1 (7.6)		Black (1980)
USA	67.0 (11.5)	12.0 (2.5)	Puhl *et al*. (1982)
SA elite	62.7 (2.9)	14.7 (3.4)	Siroky (1990)
SA Beach	61.73 (4.5)	13.12 (2.4)	Present study

DISCUSSION

At the elite end of the performance continuum practically all elite sports performers are characterized by unique morphological attributes. Tanner (1964) indicated that athletes successful at the Olympic Games had definite body characteristics that were clearly specific to the competitive event. Although there are many attributes for success at elite levels, Khosla (1983) made the point that while an ideal physique was not sufficient in itself for excellence in sport, deficiency thereof (even in the presence of compensating attributes) may be a severe handicap when trying to fulfill one's athletic potential.

Percentage body fat is construed to be an important morphological consideration that is likely to influence beach volleyball match-play performance. This is because vertical jump performance is probably the most pre-eminent physical attribute required by elite players and is adversely affected by over fatness, in other words excess body weight in the form of fat will almost certainly lead to lower jumping ability. One might draw a tentative conclusion from observing Table 8 that the greater vertical jump performances reported for the USA and Canadian indoor volleyball teams in relation to the present study are at least in part related to their relatively low body fat (Puhl *et al*., 1982; McGowen *et al*., 1990; Smith *et al*., 1992).

Isokinetic measurement and strength

Anderson *et al*. (1991) indicate that the assessment of strength of the athlete in the sports medicine setting has traditionally been in one of three modes, either isometrically, isotonically or isokinetically, using concentric muscle contractions. However, the attraction of utilizing an isokinetic dynamometer device is linked largely to the increased sophistication of data produced, which can be expressed in a variety of units, including torque, work and power, at different speeds (degrees $\cdot s^{-1}$).

Van Heerden (1996) elaborates upon the essential goals of isokinetic dynamometer usage and identifies the importance of the assessment of muscular function to identify asymmetry (bilateral or ipsilateral) or weakness. Such data, according to the same author, has relevance for three distinct reasons;

a) the prevention of injuries due to muscle imbalance;
b) ascertaining specific goals for resistance training programmes, and
c) providing guidelines for orthopaedic rehabilitation and for resuming sports participation after injury.

Oberg *et al*. (1986) make the observation that muscle strength at different speeds varies between athletes. They continue by saying that it is important to know the 'normal' torque values of athletes so as to better understand functional imbalance or muscle weakness that may be evident in that sporting code. Data has been produced in this respect on several sports, including ski racing (Haymes & Dickinson, 1980), jumping and sprinting (Thorstensson *et al*., 1977), basketball (Clark *et al*., 1979), ice hockey (Smith *et al*., 1981) grid iron football (Stafford & Grana, 1984) and soccer (Oberg *et al*., 1986), but none according to the literature with regard to the sport of beach volleyball.

It is of interest therefore to see whether elite beach volleyball players have developed relatively strong leg muscles, notably the quadriceps and hamstring groups as a result of running and jumping on sand, and to identify the typical quadriceps/hamstring ratios of elite players.

Absolute dynamic strength

Table 2 presents the mean absolute peak quadriceps and hamstring torque of 13 elite South African beach volleyball players. The data presented appears to illustrate the high degree of comparability between left and right leg during extension and flexion; further evidence of this is shown in Table 4 showing the small bilateral variations in terms of percentage difference.

The mean quadriceps peak torque was significantly greater ($p<0.05$) than that exhibited by the hamstring at all testing speeds; 60, 180 and 240 degrees $\cdot s^{-1}$ (See Tables 5, 6 and 7). This finding according to Van Heerden (1996) is to be expected and can be found in practically all studies involving quadriceps and hamstring assessments.

It has been previously stated that one should exercise some caution when comparing and extrapolating results from one study to another, especially where different isokinetic devices have been used (Francis & Hoobler, 1987; Thompson *et al*., 1989). However, whilst taking cognisance of potential variations in data reliability from different studies, it was thought worthwhile to compare quadriceps and hamstring performance data from previous analyses of sports teams with the present study.

The tentative assumption was that the increased effort of running and jumping on sand may have led to elite beach volleyball players having relatively strong legs when compared to other athletes who perform on non-compliant terrains. This appears to have been borne out, when one draws comparison with previous studies, where compatible testing speeds were used. Thus beach volleyball players in the present study had greater peak torque results than those reported by Puhl *et al*. (1982) for elite indoor volleyball at 180 and 240 degrees $\cdot s^{-1}$, and in the following sports: professional and elite ice hockey players at 180 degrees $\cdot s^{-1}$ (Smith *et al*., 1981), school grid iron football players at 60 and 240 degrees $\cdot s^{-1}$ (Schlinkman, 1984), college grid iron football players at 180 degrees $\cdot$ s^{-1} (Stafford & Grana, 1984), Swedish national soccer team at 60 and 180 degrees $\cdot$ s^{-1} (Oberg *et al*., 1986) and rugby players at 60 degrees $\cdot$ s^{-1} (Van Heerden, 1996).

Relative isokinetic strength

Previous research has shown that variation in mean torque output during leg extension and flexion can be attributed to age, sex and body mass (Watson & Donovan, 1977; Beam *at al*., 1982). Davies (1987) has indicated that the best methodological approach when evaluating strength is to use a speed of 60 degrees $\cdot$ s^{-1} which in the present study elicited a mean relative isokinetic strength of 3.29 Nm $\cdot$ kg^{-1} for the quadriceps and 1.86 Nm $\cdot$ kg^{-1} for the hamstrings. Davies (1987) also suggests after investigating the peak quadricep femoris and muscle output of professional grid iron football players that a value of 3 Nm $\cdot$ kg^{-1} is desirable. The relative muscle strength exhibited by the beach volleyball players at 3.29 Nm $\cdot$ kg^{-1} is above the guideline suggested by Davies (1987) and lends further credence to the observation that exercise on a sand terrain is likely to result in beneficial strength development in relation to body mass.

Bilateral and ipsilateral muscle ratios

Analysis of the data presented in Table 4 on bilateral ratios suggest that beach volleyball players have a high degree of parity between left and right leg extensors and flexors at 60, 180 and 240 degrees $\cdot$ s^{-1}. Previous studies have identified that a reason for bilateral variation may be due to the subject's being characterized by a dominant leg. However, there is some ambivalence in the literature as to what 'dominance' means. Some authors have identified it as the leg preferred for kicking (Wyatt & Edwards, 1981; Holmes & Alderinck, 1984) while others consider it to be the stronger leg (Goslin & Charteris, 1979). Perhaps the beach volleyball players in the present study are less likely to be characterized by a 'dominant' leg, because the take-off technique in both the spike and block jumps require a double footed simultaneous contraction of the muscles of both legs. This is somewhat different to basketball and high jumping where a favoured leg is used predominantly for jump take off, or in soccer where players prefer to use one foot for kicking, which may result in bilateral performance differences between the left and right leg. According to Van Heerden (1996) another factor one should be aware of concerning the lack of bilateral variance, is that it may be an indication that the beach volleyball players were largely free from injury.

According to Knapik and Ramos (1980) the ipsilateral muscle ratio, more commonly referred to as the hamstring/quadriceps ratio, varies between 50% and 62% in healthy people. Studies of athletes have indicated that this may vary according to the activity or sport they are actively involved in. For example Gilliam *et al*. (1979) showed that flexion/extension ratios for high school grid iron football players was 60% at 30 degrees $\cdot$ s^{-1} and 77% at 180 degrees $\cdot$ s^{-1}. Stafford and Grana (1984) and Schlinkman (1984) also found an increasing ratio with increasing velocity in gridiron football players. This pattern was also consistent with the findings of Oberg *et al*. (1986) who reported that national soccer players had a flexion/extension ratios of 60.8% at 30 degrees $\cdot$ s^{-1} and 74.6% at 180 degrees $\cdot$ s^{-1}. The present isokinetic results of elite South African beach volleyball players, also identified a similar ipsilateral ratio trend cited in the aforementioned studies. This was manifested by an increasing hamstring/quadricep ratio with testing velocity, which was 57.0% at 60 degrees $\cdot$ s^{-1}, 62.5% at 180 degrees $\cdot$ s^{-1} and 64.3% at 240 degrees $\cdot$ s^{-1}.

Vertical jump performance

Sargent (1921) proposed that the vertical jump was a measure of general muscle power, which is not essentially correct, because as Siroky (1990) observed, it lacks the dimensions of power as a true measure ($\text{power}=\text{work} \cdot \text{time}^{-1}$). However in practical terms other studies have identified a strong correlation (r=0.92) between vertical jump performance when measured in cm and peak power output calculated from data recorded on a force platform (Davies & Young, 1984). Thus, the measurement of vertical jump performance is conceivably the most widespread method to assess power output in athletes and sportsmen (MacLaren, 1990).

It has been previously mentioned that the ability to play the ball at high elevations is a highly desirable attribute for the elite beach volleyball player (Davies *et al*., 1998). Perhaps the two most influential factors that affect aerial contact ability in well trained players are stature and vertical jumping performance.

Clearly one’s stature is genetically determined and on reaching maturity will remain the same. However VJP can vary considerably depending upon the type of training and sport that an individual plays. The literature indicates that elite indoor volleyball players have generally the best vertical jump ability of any team sport participant (MacLaren, 1990). Due to the obvious similarities in match-play, one might presuppose that beach volleyball players are also characterized by exceptional VJP.

There has been a certain preoccupation with the role that muscular strength and various methods of strength training have upon vertical jump performance (Bangertner, 1968; McKethan & Mayhew, 1974). According to Aragon-Vargas & Gross (1997) less attention has been given to other factors that are integral to VJP. These factors have been investigated, but probably warrant greater attention, notably the storage and utilization of elastic energy during VJP (Asmussen & Bonde-Peterson, 1974; Komi & Bosco, 1978), motor control of the locust jump (Heitler & Burrows, 1997a, 1997b), the relative contributions of joint and segment actions to the jump (Pandy & Zajac, 1991), and issues concerning the coordination of segmental actions (Bobbert & Van Ingen Schenau, 1988).

However, little if any consideration has been given to the influence that training on a compliant terrain may have upon VJP. Simply put, does training (jumping) and/or playing beach volleyball on sand positively influence vertical jump performance, especially when measured on a hard surface? The results of VJP of 13 elite beach volleyball players are shown in Table 8, in comparison with VJP of national indoor volleyball teams.

The VJP of the 13 elite beach volleyball players studied, was 61.7 cm, which on average is considerably lower when compared to studies of indoor national teams (See Table 8). This may be partly due to the fact that the movement kinetics that occurs during sand jumping do not automatically translate into improved VJP on a hard surface. Specificity of training is an important factor if any form of improvement is to be experienced by elite sports performers. It may well be the case that the unique compliant qualities of sand and the training adaptations made by the performer are predominantly related to the training surface. Thus jump training on a sand surface is more likely to result in an improvement in VJP on a sand surface, but less so on a hard surface, and vice versa. Thus, any anticipated cross-over effects of training by elite athletes on one surface and expecting a performance improvement on another, are likely to be less than when the nature of both training and playing surfaces are held constant. In support of this theory are the many anecdotal reports by international indoor players who experience considerable difficulty with regard to jumping effectively in sand when they convert to beach volleyball (Smith & Feineman, 1988). They may have had exceptional indoor (hard court) jumping abilities, but when they play on sand they often experience a major performance decrement in their jumping ability. On the other hand, experienced elite beach volleyball players appear to have made adaptations to their jumping technique due to the compliant nature of the sand, and are subsequently better able to optimize VJP specifically on sand.

CONCLUSION

It would appear that human physical performance is affected by the type of terrain upon which one moves. In this instance a select group of male elite beach volleyball players who regularly walk, run and jump on sand during the course of match-play and training were investigated. It was found that their leg strength when measured by isokinetic devices at three speeds (60, 180 and 240 degrees $\cdot$ s^{-1}) was superior to those cited in previous studies in sports and athletic activities performed on non-compliant (hard) surfaces. The tentative conclusion is that human locomotion on sand appears to accommodate specific biological adaptations that include the development of superior leg strength.

Leg power as ascertained by vertical jump performance was however, somewhat ambiguous in terms of the assumed performance improvements as a result of running and jumping in sand. The anticipated performance benefits from regular physical exertion on sand for VJP on a hard surface were less than expected. Thus, one might conclude that the mechanics and energetics that typify sand jumping, especially the apparent loss of stored elastic energy and the possible compensations made, do not in the final analysis necessarily assist in optimising VJP on a hard terrain.

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