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ANTHROPOMETRIC AND STRENGTH CHARACTERISTICS OF TENPIN BOWLERS WITH DIFFERENT PLAYING ABILITIES

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ABSTRACT: The primary purpose of this study was to investigate the strength and anthropometric characteristics of elite and semi-elite tenpin bowlers as compared to non-bowlers, and to establish whether it was possible to discriminate playing level through selected predictor variables. Elite and semi-elite bowlers were distinguished by their bowling score average (BS_{ave}), with participants scoring 200 pin falls and above assigned to the elite group. Eighteen elite bowlers (M=10, F=8; BS_{ave} 213.2±6.80), 12 semi-elite bowlers (M=7, F=5; BS_{ave} 181.3±9.36) and 33 sedentary university students (M=14, F=19) were recruited. Anthropometric measurements were taken and isometric arm strength was recorded. Between-group differences were identified through a two-way ANOVA, while discriminant analysis was used to predict group membership. For anthropometric characteristics, the results indicated that the elite bowlers were heavier, had longer lower leg and hand length and had a wider arm span as compared to the non-bowlers. The elite group also had stronger forearm/wrist internal rotation compared to non-bowlers. In addition, the male elite group were stronger than the non-bowling group for arm flexion. There appeared to be a 54% success rate for predicting group membership from selected anthropometric and strength discriminating variables, with forearm/wrist internal rotation strength being the best discriminating variable. It is suggested that coaches should benefit by selecting larger built bowlers with long limbs. Furthermore, bowlers could potentially gain by paying extra attention to increasing the strength levels of forearm/wrist internal rotators and arm flexors during training. These findings also provide normative data for elite and semi-elite bowlers.

KEY WORDS: bowling, prediction, discriminant analysis

INTRODUCTION

The sport of tenpin bowling has been played since ancient times and is widely accepted as a sport at a recreational level. It was only recently recognized as a competitive sport with its acceptance into the Commonwealth (since 1998) and Asian Games (since 1978) as a medal sport. Since then, the governing body for tenpin bowling, Federation Internationale des Quilleurs (FIQ), has been pushing ultimately for its inclusion in the Olympics in the near future.

Over the years, tenpin bowling has attracted various types of participants, both large and small. It is argued to be a sport for all [4,24] and has also been labelled a gender neutral sport [20], as it involves a seemingly low reliance on absolute strength, power and fitness [16]. Consequently, it is relatively common to have women's scores equalling or even exceeding the men's.

Currently, it is estimated that there are approximately 100 million bowlers worldwide, with about 10 million participating competitively [6]. Yet, research in tenpin bowling is surprisingly scarce [16]. Even more lacking are studies related to physical and physiological parameters, with a handful of older unpublished studies [5,8,14,23] and only two recently published works [16,17]. A majority of these studies are in disagreement over the relationship between strength and anthropometric variables with bowling performance. Some studies have found significant relationships [5,14], while others have not [8,17,23].

Considering the small number of empirical studies conducted to date, there is a need to further explore the influence of strength and anthropometric variables on bowling performance and identify how bowlers of different playing abilities differ in terms of these variables. A number of studies on anthropometric and strength characteristics have successfully managed to discriminate between elite and novice athletes in a multitude of sports. These include studies on handball [11], volleyball [7], water polo [18], rowing [2], kayaking [22], soccer [13] and American football [1]. More recently, there have been studies that were also able to statistically classify player position of a team sport by analysing the anthropometric and strength data [18,19]. For example, it was demonstrated that it was possible to differentiate players of different competition levels as well as players of various playing positions in water polo using anthropometric and fitness characteristics [18].

In tenpin bowling, no study has tried to discriminate bowlers of different playing abilities by utilizing strength and anthropometric attributes. One study was carried out to differentiate bowlers of different levels, but it used physiological parameters. In that study, the authors commented that it was difficult to differentiate the good from average bowlers just by looking at the selected physiological measures [16].

Therefore, the primary purpose of this study was to investigate whether there were differences in selected anthropometric and strength characteristics between elite, semi-elite and non-bowlers. A secondary purpose was to establish whether it was possible to discriminate playing level through selected predictor variables. It was expected that differences would be detected between the two levels of bowlers as well as between the bowlers and non-bowlers. It was also hypothesized that it would be possible to successfully discriminate these groups using the selected anthropometric and strength characteristics.

MATERIALS AND METHODS

Subjects. A total of 30 national and state bowlers who were in competition during the current season and had various competitive years of experience were recruited. Subjects were assigned to either elite or semi-elite groups according to their average bowling score (BS_{ave}) over three major tournaments nearest to the data collection date. Subjects with a BS_{ave} of 200 pin falls and above were placed in the elite group, while the other bowlers were placed in the semi-elite group. There were 10 male elite (age 23.6±3.9; experience 11.2±3.7 years), 8 female elite (age 22.4±5.4; experience 8.1±5.2 years), 7 male semi-elite (age 20.6±2.4; experience 4.9±2.3 years) and 5 female semi-elite bowlers (age 20.6±4.0; experience 5.8±1.3 years). This number of elite and semi-elite subjects represented the entire population of bowlers in the Malaysian senior and back-up national teams. Subjects for the non-bowler group comprised 33 randomly chosen first and second-year undergraduate students who were not involved in any competitive sport. There were 14 male students (age 22.0±1.6) and 19 female students (age 22.6±1.3). All subjects signed and returned an informed consent form, which was in accordance with institutional ethical guidelines. Parental consent was obtained for subjects under the age of 18 years.

Procedures

Data collection was carried out for three days. Measurements for each subject were taken in the first half of the day on one of the three days, prior to the commencement of their regular training session. The measurements were performed according to the ethical standards of the Helsinki Declaration.

Anthropometric test battery

Participants were subjected to seven anthropometric measurements: height, weight, seated height, bi-iliac breadth, arm span, dominant hand length and tibial length. Leg length was calculated by subtracting seated height from standing height, and from this value, the ratio of seated height to leg length (SH:LL ratio) was generated. Measurement equipment consisted of a wall-mounted stadiometer (SECA, Germany) for height, calibrated balance weighing scale (DETECTO, Missouri) for weight and a small and large sliding caliper (LAFAYETTE, Indiana) for segment length and breadth. Data collection methods were as per convention listed in the anthropometric standardization reference manual [10]. Three non-consecutive measurements for each site were taken according to a specified sequence and the median score was used. Only one tester collected the anthropometric measurements throughout the study.

Isometric arm strength test battery

Peak isometric strength test was used and seven variables were measured: finger pinch for the index to thumb, middle finger to thumb, and third finger to thumb, arm flexion (at approximately 90 degrees), wrist flexion (at full extension), forearm/wrist internal rotation (FIR) and forearm/wrist external rotation (FER) (see Figure 1). Three non-consecutive measurements according to a predetermined sequence were carried out for the dominant arm, with the maximum score used in the analysis. All scores were normalized to body weight (kg force/kg body mass x 100). A Lafayette Manual Muscle Tester (load cell) was the measurement tool and it was used in conjunction with a custom made steel apparatus to isolate different segments of the arm.

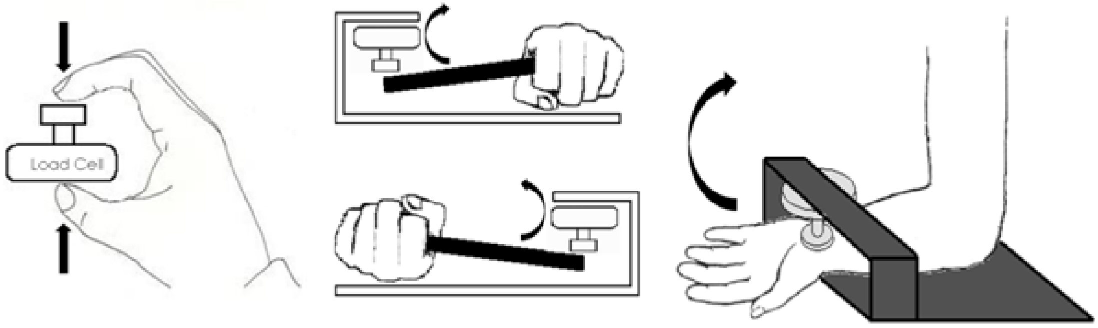

FIG. 1. FINGER PINCH TEST, FOREARM ROTATION TEST AND ARM FLEXION TEST

Statistical analyses

Differences in the anthropometric and strength characteristics between elite, semi-elite and non-bowlers were compared using a two-way (group x gender) ANOVA, with alpha level set at .05. Where there was a significant main effect for group, a Tukey post-hoc test was conducted. For dependent variables with a significant interaction effect, separate one-way ANOVAs for males and females were carried out. Discriminant analysis was used to reveal whether the selected variables could successfully predict group membership.

RESULTS

The results indicated that there were no significant group differences for age, F (2,57)=2.36, *p*=0.10, or gender, F (1,57)=0.06, *p*=0.80. Although the bowling groups were formed based on their BS_{ave}, a Mann-Whitney U test revealed that there were no significant gender differences in BS_{ave} between the elite males and females, U=37.0, Z=-0.27, *p*=0.41, and between the semi-elite males and females, U=16.5, Z=-0.16, *p*=0.44.

Anthropometric characteristics

Mean anthropometric scores are reported in Table 1. There was a significant interaction effect for SH:LL ratio. Follow-up analyses using separate t-tests for the three different groups revealed that the SH:LL ratios for males and females were significantly different only for the semi-elite, t(10)=50.06, *p*<0.001, and non-bowler groups, t(31)=3.16, *p*=0.004. There were no group differences within each gender.

There were significant main effects for gender in height, weight, tibial length, arm span and hand length. In addition, there were significant main effects for groups in terms of weight, tibial length, arm span and hand length. For body weight, the elite bowlers (M=68.67±12.88 kg) were heavier that the non-bowlers (M=57.97±11.24 kg). Both elite (M=38.19±2.21 cm) and semi-elite bowlers (M=38.19±3.20 cm) had longer tibial length than the non-bowlers (M=35.65±2.13 cm). Similarly, elite (M=1720.08 ±80.08 cm) and semi-elite (M=172.63±12.85 cm) bowlers had longer arm span compared to the non-bowlers (M=163.99±9.67 cm). For hand length, the elite bowlers' hands (M=18.56±10.04 cm) were longer than the non-bowlers' hands (M=17.62±10.07 cm).

Isometric upper limb strength characteristics

Mean strength scores are reported in Table 2. There was a significant interaction effect for arm flexion. Follow-up analysis using a separate one-way ANOVA for each gender revealed that there was a significant

TABLE 1. AVERAGE BOWLING SCORE AND ANTHROPOMETRIC MEASURES OF ELITE BOWLERS, SEMI-ELITE BOWLERS AND NON-BOWLERS (REPORTED AS MEAN ±SD)

	Male			Female		
	Elite	Semi-Elite	Non-Bowlers	Elite	Semi-Elite	Non-Bowlers
BS_{ave} (pin falls)	213.80 ± 7.69	180.67 ± 8.18	Not Applicable	212.53 ± 5.92	182.29 ± 11.78	Not Applicable
Height (cm) †	170.72 ± 8.74	171.87 ± 8.34	167.18 ± 7.34	162.61 ± 4.81	159.02 ± 7.21	156.98 ± 4.56
SH:LL Ratio* †	1.05 ± 0.04	0.99 ± 0.03	1.02 ± 0.06	1.06 ± 0.06	1.10 ± 0.47	1.08 ± 0.45
Weight (kg) † ‡	69.59 ± 12.89	67.99 ± 19.92	66.67 ± 13.72	67.51 ± 13.66	56.56 ± 5.44	53.58 ± 9.43
Tibial Length (cm) † ‡	39.02 ± 2.28	40.07 ± 2.56	37.18 ± 1.83	37.15 ± 1.72	35.56 ± 1.88	34.52 ± 1.59
Armspan (cm) † ‡	176.23 ± 7.11	180.49 ± 9.03	172.09 ± 8.19	166.89 ± 6.18	161.62 ± 8.51	158.03 ± 5.41
Hand Length (cm) † ‡	18.82 ± 1.13	19.31 ± 1.30	19.38 ± 1.13	18.24 ± 0.89	17.08 ± 0.86	17.06 ± 0.58
Biiliac Breadth (cm)	27.98 ± 3.78	27.24 ± 3.30	26.96 ± 1.78	27.45 ± 2.79	26.50 ± 1.52	26.24 ± 1.17

Note: * Significant Interaction Effect (p<0.05); † Significant Main Effect for Gender, significant difference (p<0.05) between males and females; ‡ Significant Main Effect for Group (p<0.05)

TABLE 2. NORMALIZED ISOMETRIC UPPER BODY STRENGTH MEASURES OF ELITE BOWLERS, SEMI-ELITE BOWLERS AND NON-BOWLERS IN KG FORCE/KG BODY MASS X 100 (REPORTED AS MEAN ±SD)

	Male			Female		
	Elite	Semi-Elite	Non-Bowlers	Elite	Semi-Elite	Non-Bowlers
Index Finger to Thumb Pinch †	8.46 ± 1.49	8.70 ± 2.01	7.47 ± 1.34	6.42 ± 1.24	7.27 ± 1.90	6.60 ± 1.51
Middle Finger to Thumb Pinch †	7.10 ± 1.95	7.33 ± 1.85	5.97 ± 2.07	6.62 ± 1.55	5.04 ± 1.11	5.75 ± 1.57
Third Finger To Pinch	4.06 ± 1.38	5.22 ± 1.45	4.10 ± 1.44	3.99 ± 1.30	3.71 ± 0.84	3.97 ± 1.03
Arm Flexion * † ‡	§ 35.31 ± 5.16	30.17 ± 6.59	§ 26.51 ± 4.04	21.40 ± 5.12	19.72 ± 6.15	20.78 ± 5.07
Wrist Flexion †	20.13 ± 2.77	18.33 ± 3.95	16.46 ± 2.42	12.98 ± 3.77	13.62 ± 3.70	12.54 ± 2.52
Forearm Internal Rotation † ‡	7.63 ± 1.95	6.05 ± 1.23	5.41 ± 1.28	4.33 ± 0.91	4.10 ± 0.86	3.57 ± 0.96
Forearm External Rotation †	6.79 ± 1.71	6.79 ± 1.49	5.95 ± 1.31	4.25 ± 0.96	3.98 ± 1.01	4.34 ± 1.03

Note: * Significant Interaction Effect (p<0.05); † Significant Main Effect for Gender, significant difference (p<0.05) between males and females; ‡ Significant Main Effect for Group (p<0.05); § Significant difference between groups (p<0.05), from separate one-way ANOVA for males and females difference for the male group, F (2,57)=8.88, p=0.001, whereby the male elite bowlers had significantly higher arm flexion scores compared to the male non-bowlers. Differences between female elite bowlers and female non-bowlers were not detected.

There was a significant main effect for gender whereby the males recorded higher scores in the pinch strength for the index to thumb and middle finger to thumb as well as for arm flexion, wrist flexion, FIR and FER. Meanwhile, there was a significant main effect for group in only FIR. The elite bowlers (M=6.17±2.28) had stronger FIR compared to the non-bowlers (M=4.35±1.42).

Discriminant analysis

Selection of variables to be included in the discriminant analysis was based firstly on whether there was a significant difference between groups for the specific variables. Subsequently, weight, tibial length, arm span, hand length, arm flexion and FIR were shortlisted (see Table 1 and 2). Secondly, to adhere to the multicollinearity assumption, shortlisted variables that had high co-correlation (r>0.05) were omitted. Consequently, only weight, hand length and FIR were used as discriminating variables in the analysis. Box's M test indicated that the assumptions of equality of variance-covariance matrices were met.

The discriminant analysis indicated the presence of two functions. The first indicated an emphasis on the strength and mass dimension while the second reflected the anthropometric dimension more. Only the first function was significant (p=0.002), but the model only explains 28.8% of variation in the grouping variable. The cross-validated classification showed that, overall, 540.0% of the participants were correctly classified. Within each group, 55.6% of the elite, 16.7% of the semi-elite and 66.7% of the non-bowlers were correctly placed in their respective groups. There were high (r>0.30) loadings for all variables in the first function, with FIR being the best predictor (see Table 3).

TABLE 3. DISCRIMINANT FUNCTION RESULTS

	Structure Matrix of Function		Discriminant Function Coefficients
	1	2	Unstandardized Coefficients
Forearm Internal Rotation	0.737*	0.038	49.119
Weight	0.586*	0.042	0.057
Hand Length	0.577	0.785*	-0.068
Constant			-4.780

Note: * Largest absolute correlation between each variable and either discriminant function

DISCUSSION

The purpose of this study was to examine whether elite bowlers had different anthropometric and strength characteristics as compared to semi-elite bowlers and a sample of a non-bowling population. The bowling groups were distinguished based on a single performance variable, which was the BS_{ave}. Unlike the findings of other authors [16], the BS_{ave} of the males and females in both the elite and semi-elite groups did not differ significantly. Instead, the results of this study supported the notion that bowling was a gender neutral sport and was in line with the psychological and psychomotor findings of another study [20].

Although there were no gender differences in terms of bowling performance, there were significant differences between males and females in a number of anthropometric and strength variables. Males were taller, heavier, had longer limbs and had stronger finger pinch, arm and wrist flexion as well as forearm/wrist rotation strength. These results are similar to previous research findings and the common understanding that there are gender differences in the physical characteristics of athletes [7,16] and the normal population [25].

More importantly, in terms of group differences for anthropometric variables, the results indicated that bowlers and non-bowlers were quite different. Elite bowlers were heavier than the non-bowlers. In addition, the elite and semi-elite bowlers had significantly longer upper limbs and lower leg length compared to the non-bowling counterparts, although they did not significantly differ in stature. A number of other studies have shown that there was a relationship between anthropometric characteristics and sport performance. Body mass has been shown to be positively correlated with throwing velocity [21] and kicking prowess [26]. At the same time, longer limbs have been shown to be positively related to better over-arm throwing performance [12]. An early study also found that longer arm span correlated with better bowling scores [5].

In tenpin bowling, the whole arm can be assumed to be a fixed rod with a ball held at one end and the shoulder joint as the point of rotation. For an equivalent swing velocity, an increase in the arm length will theoretically lead to an increase in the tangential velocity of the ball (tangential velocity = angular velocity x radius). Hence, it is possible that individuals with longer limbs would have an advantage in bowling as higher ball release speeds can be generated. With modern bowling considered to be a power game [4,24], this would mean that the longer radius provided by the longer segments and larger muscle mass would be the desired foundation towards becoming a good bowler. Consequently, talent identification programmes in bowling may benefit by paying particular interest to young bowlers with above average build and upper limb length.

The results of the isometric strength tests of this study provided some support for the studies [5,14] that demonstrated a positive relationship between strength and bowling performance. Of the seven strength variables, significant differences between groups were only detected in FIR and arm flexion. More specifically, the results showed that FIR strength was higher for the elite bowlers as compared to the non-bowlers. With forearm/wrist rotators as the most likely primary generators of the tremendous ball spin commonly seen in the modern game and considering that skilful and experienced players impart huge amounts of spin to the bowling ball, it is possible that the elite bowlers developed stronger internal rotators of the forearm/wrist region, having amassed much more practice and playing years. A study on handball corroborated this possibility of strength increasing with playing years whereby the authors showed that ball throwing velocity and strength greatly increased with just one regular season of active competition [9]. Comparatively, an elite bowler participates in various competitions and is in active training for 9 to 10 months in a year [4].

There is also another possibility that the physical requirements of the sport contributed to the differences in the FIR between the elite and non-bowling group. A common misconception is that bowling is not a physically challenging sport [20,24]. In reality, a bowler swings a 12 to 16 pound ball, 12 to 21 times a game, for usually six games a day, during competition. Each swing is executed at a considerable speed to generate high ball momentum. It has been argued that a decent amount of muscle strength and muscle endurance is required for the execution of the delivery [16,17]. Hence, the participants in the elite group could have possessed a higher degree of FIR strength which was required to be successful in the sport.

As for arm flexion strength, the follow-up ANOVA revealed that the male elite bowlers were stronger than their non-bowling counterparts. This result appeared logical considering that the arm flexors play an integral role in the forward motion of the forearm in the final phase of the swing. However, the female elite bowlers did not appear to be stronger than the female non-bowlers. There could be two possible explanations for the contrast between genders. Firstly, the females may have employed a different strategy in their swing; instead of utilizing a lot of strength, they relied on optimum technique to achieve the same competitive scores. Female bowlers may have concentrated on spin and accuracy rather than outright ball speed. This possibility is supported by a swimming technique study whereby the female swimmers employed a different front crawl technique to achieve the same effective velocity as males [15]. Alternately, it is also likely that as the strength of bowlers increased over the period of participation, these changes were possibly more apparent in the men due to hormonal differences [3].

Interestingly, finger pinch strength did not differ between the groups. It was assumed that a strong finger grip was needed to have good control of the heavy bowling ball, but the results did not support this assumption. It is likely that proper ball grip technique was more important than outright finger strength when it came to handling the ball. This result is in agreement with one study that found that hand grip strength was not correlated with bowling scores [16]. The authors suggested that there was a strength threshold that was needed to bowl competitively, after which further strength gains were not essential. Nonetheless, results from the strength tests provide a useful input for coaches in terms of highlighting the necessary muscle groups that need to be trained to be competitive in bowling.

Finally, this study also explored the possibility of discriminating the elite, semi-elite and non-bowlers based on selected anthropometric and strength predictor variables. A number of studies have successfully demonstrated that it was possible to statistically discriminate good and not so good players in various sports [1,2,7,11,13,18,22]. Using discriminant analysis, the generated function successfully classified 54.0% of the participants into their respective groups. In a three-group setting such as in this study, there was a 33.33% probability of placing a group member in the correct group by chance; hence, an overall prediction accuracy that is double the value of chance would have been ideal. In a two-group study using discriminant analysis, a prediction accuracy of 87.2% between elite and non-elite handball players was possible [11].

Based on the current results, it can be inferred that it is not entirely possible to successfully discriminate tenpin bowling playing ability from the selected physical characteristics used in this study alone. Caution must be applied in interpreting the discriminant function, as there was multicollinearity between the discriminator variables that necessitated the removal of some variables from the analysis. For future research, a different set of non-correlated variables should be used so that more predictor variables could be used in the function and possibly increase its group predicting accuracy.

From the discriminant analysis, the FIR appeared to be the biggest influence in predicting group membership. Along with the higher strength scores in the elite compared to the non-bowler group, the relevance of FIR and ball spin in modern bowling is further supported, and consequently the importance of placing emphasis on strengthening the relevant arm rotator muscles in bowler training is highlighted.

CONCLUSIONS

There were a number of differences in anthropometric characteristics between the groups. The elite bowlers were heavier, had longer lower leg and hand length and wider arm span compared to the non-bowlers. It is suggested that bowling talent identification programmes could benefit by selecting talented individuals who are well built and have long limbs as these factors increase the possibility of an individual becoming a successful bowler. There were a limited number of upper limb strength differences between the groups. Only the male elite bowlers were stronger in arm flexion than their non-bowling counterparts, while collectively, the elite bowlers had stronger forearm/wrist internal rotation compared to the non-bowlers. From these isometric strength test results alone, it was difficult to identify whether elite bowlers became stronger as a result of longer playing time or had become better bowlers because they were stronger. Predicting group membership using the selected anthropometric and strength measurements was only moderately successful, with forearm/wrist internal rotation strength proving to be the best discriminating variable. It is recommended that bowlers and coaches pay particular attention to forearm/wrist internal rotators and the arm flexors during strength training. Lastly, anthropometric and strength normative data for elite and semi-elite bowlers in Malaysia have been established as a result of this study and are readily available as a reference.

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