Psychology Research, August 2019, Vol. 9, No.8, 329-334
doi:10.17265/2159-5542/2019.08.003

Haptic Perception of Physical and Functional Properties of Table Tennis and Badminton Rackets in Children and Elderly*

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The haptic perception affords detection of the physical and functional properties of an instrument actively sustained. Fifty-seven children (8.82 ± 0.38 years old) and 64 elderlies (71.3 ± 4.46 years old) estimated the length and the distance of the center of percussion for two table tennis rackets and a badminton racket. The eigenvalues of each racket for length and distance from the wrist to the center of percussion were calculated. The present study confirmed the results obtained with field tennis rackets, extending them to table tennis and badminton rackets, and also to children. The elderlies preserved and children had the capacity of haptically detect physical and functional properties of table tennis and badminton rackets. The weight of the rackets affected properties estimations. The eigenvalues may be a valid tool for the definition of physical and functional properties of sport instruments, allowing better adjustment to different motor development stages.

Keywords: haptic perception, rackets, eigenvalues, children, elderly

The haptic perception affords detection of the physical and functional properties of a sport instrument, actively sustained without visual information (Turvey, 1996; Turvey & Carello, 1995). However, the estimation of the physical property objects' length increases with its weight (Kloos & Amazeen, 2002). The functional property center of percussion is the area, in the strings of a racket, where the greatest amount of potency is transmitted to the ball, and where the impact transfers less vibration to the hand that wields the instrument, because the impact results in minimal reactive forces (Cooper, Carello, & Turvey, 1999). The purpose of a racket is to strike a ball; therefore, the detection of this property is important for such an essential task.

It is possible to represent the resistance to the action of lifting and moving an object wielded through eigenvalues. These values are obtained via a symmetric 3 × 3 matrix, whose large diagonal quantifies the moments of inertia, reflecting the possible asymmetric mass distribution of the object (Fitzpatrick, Carello, &

* **Acknowledgement:** This study was partially supported by the Park of Science and Technology of Alentejo (ALENT-07-0262-FEDER-001883), and by the Quality of Life Research Centre (CIEQV—Polytechnic Institute of Santarém branch).

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Turvey, 1994) and, consequently, instrument properties haptically detected by the actor.

Adults and elderly can detect length and center of percussion in field tennis rackets (Carello, Thuot, Anderson, & Turvey, 1999; Carello, Thuot, & Turvey, 2000). Beak, Davids, and Bennett (2000) compared children and adults with a field tennis racket, whose center of mass was manipulated, and found that children preferred those rackets with lower moments of inertia values. However, we have not found studies for other kind of rackets or comparing children haptic capability with older groups. So, the purposes of this paper are to analyze: (i) haptic capability of children and elderly to detect the length and the center of percussion of table tennis and badminton rackets; and (ii) eigenvalues expression according to different rackets properties and actors’ morphologies.

Method

Participants

For badminton racket, 30 children (8.93 ± 0.25 years old, 17 girls) and 37 elderlies (8.93 ± 0.25 years old, 23 women) participated. For table tennis rackets, the sample consisted of 27 children (8.82 ± 0.38 years old, nine girls) and 27 elderlies (71.3 ± 4.46 years old, 22 women). Informed consent was obtained from elderlies and parents and children gave their assent.

Materials and Procedure

The protocol was similar to Carello et al. (1999). With their forearm supported on a small table, participants held a racket in their right hand. The racket was hidden by a curtain. With the left hand, they used a hand crank to move a ball, to indicate their estimates of the center of percussion’s length and distance (“at what distance would you hit the ball?”), for each racket (see Figure 1). No time limitation was imposed. The participants remained unaware of which object they were holding.

Figure 1. Experimental conditions: table tennis racket (left) and badminton rackets (centre-left and centre-right). The picture on the right shows the device that was used to indicate the length and the distance for the rackets’ centre of percussion.

Participant performed a trial per condition for the three different rackets: light table tennis (length—26.2 cm, weight—97 g, and center of percussion—18.1 cm), heavy table tennis (length—25.7 cm, weight—176 g, and center percussion—18 cm), and badminton (length—66.3 cm, weight—95 g, and center percussion—54.2 cm). Notice that the light table tennis and the badminton rackets had similar weights. The order of presentation of rackets and estimates of the locations were alternated between participants.

The wrist breath and thickness, and the distance from the wrist joint center to the center of mass of each racket were collected for each participant. The eigenvalues of each racket for length and distance from the wrist to the center of percussion were calculated according to Fitzpatrick et al. (1994), Stroop, Turvey, Fitzpatrick, and Carello (2000), and Winter (1990).

Statistical Analysis

For statistical data treatment, Shapiro-Wilk test was used to verify normal distribution. For within comparisons, Wilcoxon test (*Z*) was used; and for between comparisons, Mann-Whitney (*U*) test was used; because of absence of homoscedasticity, both with Monte Carlo test verification, effect size (*r*), and Wilcoxon rank-biserial correlation coefficient or Mann-Whitney Glass rank-biserial correlation (*rrb*) estimation. For comparison among estimations and real measures, One Sample *t*-test was used, with Bootstrapping verification. Kruskall-Wallis test (*H*) was used for comparison between rackets, with Kruskal Wallis effect size eta-squared measure estimation (η^2_H), followed by Mann-Whitney (*U*) test for posttest comparisons, both with Monte Carlo test verification, and Jonckheere-Terpstra estimation (*J-T*), with Monte Carlo test verification. Confidence level was 0.05, two-sided.

Results

Obtained eigenvalues sustained the theoretical model of Turvey and Carello (1995). Moreover, moments of inertia, products of inertia, and consequently eigenvalues were different in the two age groups (see Tables 1 and 2), which highlight the interaction between intrinsic and extrinsic constraints. Elderly anthropometric measures where greater than the children's, and the extremity of each racket was more distant from their axis of rotation than for children, resulting in greater eigenvalues.

Table 1

Eigenvalues Estimated for Length of Table Tennis and Badminton Rackets, for Weight and Length, by Age Group (Children, Elderly)

Weight						
Racket	Light table tennis			Heavy table tennis		
Eigenvalues	I_1	I_2	I_3	I_1	I_2	I_3
Elderly	11629.4	8414.4	3815.9	13896.3	11661.0	5265.5
Children	9678.6	7155.2	3120.5	10116.6	8479.4	4261.2
Length						
Racket	Badminton			Light table tennis		
Eigenvalues	I_1	I_2	I_3	I_1	I_2	I_3
Elderly	19495.0	15679.6	4146.0	10802.7	7703.7	3494.8
Children	13321.4	10685.8	2959.8	9120.4	6690.3	2803.6

Table 2

Eigenvalues Estimated for Center of Percussion of Table Tennis and Badminton Rackets, for Weight and Length, by Age Group (Children, Elderly).

Weight						
Racket	Light table tennis			Heavy table tennis		
Eigenvalues	I_1	I_2	I_3	I_1	I_2	I_3
Elderly	9514.7	6889.9	3225.6	12698.2	11067.1	4596.2
Children	8156.7	5845.9	2907.8	8348.2	7653.8	3162.2
Length						
Racket	Badminton			Light table tennis		
Eigenvalues	I_1	I_2	I_3	I_1	I_2	I_3

Elderly	15072.1	11425.3	3977.3	8974.1	6497.4	2872.5
Children	9344.7	6888.2	2780.8	7624.2	5422.1	2575.6

The eigenvalues reflected topological differences between rackets, sustaining the hypothesis of differential contributions of each eigenvalue for the perception of the topology of the racket (Fitzpatrick et al., 1994), e.g., the eigenvalue I_1 is greater for the badminton rackets than for the table tennis ones, and I_2 increases with weight for the table tennis and the badminton racket (see Tables 1 and 2).

Accordingly, children and elderly significantly differentiated length and center of percussion in table tennis and badminton rackets (see Table 3).

Table 3

Estimates (cm) (M ± SD) for Table Tennis and Badminton Rackets (Light, Heavy), by Age Group (Children, Elderly) and by Location (Length; Center of Percussion), and Comparison (Z, p) Between These Properties; With Estimation of Effect Size (r) and Wilcoxon Rank-Biserial Correlation Coefficient (rrb)

Racket	Light table tennis		Heavy table tennis		Badminton	
Group	Children ($n = 27$)	Elderly ($n = 27$)	Children ($n = 27$)	Elderly ($n = 27$)	Children ($n = 30$)	Elderly ($n = 37$)
Length	26.2 ± 7.85	26.5 ± 9.30	27.4 ± 5.78	31.4 ± 6.96	33.9 ± 10.82	42.0 ± 9.17
Center of percussion	22.3 ± 8.33	21.6 ± 8.69	22.2 ± 7.98	27.8 ± 10.61	26.7 ± 7.19	34.0 ± 10.61
Z	2.991	3.892	3.111	2.427	3.250	4.313
p	< 0.01	< 0.001	< 0.01	< 0.05	< 0.001	< 0.001
r	0.58	0.75	0.60	0.47	0.60	0.70
rrb	0.47	0.91	0.55	0.33	0.58	0.98

Compared to elderlies, children also significantly underestimated badminton racket' length ($U(67) = 298.5$, $p = 0.001$, $r = 0.40$, $rrb = 0.46$) and center of percussion ($U(67) = 298.5$, $p < 0.05$, $r = 0.31$, $rrb = 0.36$). Relative to real rackets measures, both children and elderlies significantly underestimated racket length ($t(29) = 16.37$, $p < 0.001$, $t(36) = 16.11$, $p < 0.001$, respectively), and center of percussion location ($t(29) = 20.93$, $p < 0.001$, $t(36) = 10.50$, $p < 0.001$, respectively). Probably, elderlies motor experience allowed them to be closer to real racket properties than children (Chang, Wade, Stoffregen, & Ho, 2008); however, the lightness of the Badminton racket may have affected both age groups (Beak et al., 2000).

In fact, the results from light and heavy table tennis rackets support the hypothesis that weight induced overestimation of the length and the location of center of percussion (see Table 3), which was significant in elderly ($Z(27) = 2.46$, $p < 0.05$, $r = 0.47$, $rrb = -0.98$; and $Z(27) = 3.42$, $p < 0.01$, $r = 0.65$, $rrb = -0.98$; respectively) (Kloos & Amazeen, 2002). Additionally, for table tennis rackets no significant differences were found between children and elderlies in length and centre of percussion estimations of the light one ($U(54) = 353.5$, ns, $r = 0.03$, $rrb = 0.03$; $U(54) = 357.0$, ns, $r = 0.02$, $rrb = 0.02$); however, for the heavier one, a significant difference occurred for length estimation ($U(54) = 239.0$, $p < 0.05$, $r = 0.30$, $rrb = 0.34$), although only a tendency for centre of percussion estimation ($U(54) = 252.0$, $p = 0.06$, $r = 0.26$, $rrb = 0.31$).

Yet, the badminton racket, which was so light as the lighter table tennis one, was perceived by the children has the longest of all rackets ($H(2) = 10.18$, $p < 0.01$, $\eta^2_H = 0.10$; for the light table tennis racket, $U(57) = 254.0$, $p < 0.05$, $r = 0.32$, $rrb = 0.37$; for the heavy one, $U(57) = 222.5$, $p < 0.01$, $r = 0.39$, $rrb = 0.45$); also, sustained by significant evolution of the perception of the length of the three rackets—light table tennis, followed by heavy table tennis, followed by badminton ($J\text{-}T(3,84) = 1554.5$, $p < 0.001$). Additionally, the center of percussion of the badminton racket was significantly perceived as the most distant ($H(2) = 6.34$, $p < 0.05$, $\eta^2_H =$

0.05; for the light table tennis racket, $U(57) = 281.0$, $p < 0.05$, $r = 0.27$, $rrb = 0.31$; for the heavy one, $U(57) = 259.0$, $p < 0.05$, $r = 0.31$, $rrb = 0.36$); again, sustained by significant evolution of the perception of the length of the three rackets—light table tennis, followed by heavy table tennis, followed by badminton ($J\text{-}T(3,84) = 1457.5$, $p < 0.05$). Elderlies also presented the same pattern of results, but with stronger statistical expression, with the badminton racket estimated as the longest of all rackets ($H(2) = 33.40$, $p < 0.0001$, $\eta^2_H = 0.36$; for the light table tennis racket, $U(64) = 124.0$, $p < 0.0001$, $r = 0.64$, $rrb = 0.75$; for the heavy one, $U(64) = 186.0$, $p < 0.0001$, $r = 0.53$, $rrb = 0.63$); also, sustained by significant evolution of the perception of the length of the three rackets—light table tennis, followed by heavy table tennis, followed by badminton ($J\text{-}T(3,91) = 2172.0$, $p < 0.001$). Additionally, the center of percussion of the badminton racket was significantly perceived as the most distant ($H(2) = 21.60$, $p < 0.0001$, $\eta^2_H = 0.24$; for the light table tennis racket, $U(64) = 177.5$, $p < 0.0001$, $r = 0.55$, $rrb = 0.65$; for the heavy table tennis one, $U(64) = 336.5$, $p < 0.05$, $r = 0.28$, $rrb = 0.33$); once more, sustained by significant evolution of the perception of the length of the three rackets—light table tennis, followed by heavy table tennis, followed by badminton ($J\text{-}T(3,91) = 2011.5$, $p < 0.0001$). These results are in accordance with eigenvalues estimates (see Table 1). More importantly, these results highlight the differential contribution of eigenvalues for the capability of haptic perception in the detection of physical and functional properties of rackets, with different combinations of length and weight (Fitzpatrick et al., 1994).

Discussion

The present study confirmed the results of Carello et al. (1999), obtained with field tennis rackets, extending them to table tennis and badminton rackets, and also to children.

The results indicate that the elderly maintain the capacities of haptic perception, in accordance with the study of Carello et al. (2000), and that the children of this age group are able to use haptic perception to distinguish physical and functional properties of badminton and table tennis rackets, even of different weight. However, weight affected rackets' properties estimation (Kloos & Amazeen, 2002).

Conclusion

The results of this study sustain the hypothesis that haptic perception affords detection of diverse information, e.g., length and weight, and attunement of that information; differentiating lengths (Fitzpatrick et al., 1994).

The eigenvalues may be a valid tool for the definition of physical and functional properties of sport instruments, allowing better adjustment to different motor development stages (Beak et al., 2000).

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