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ЦЕНТР СПОРТИВНЫХ ИННОВАЦИОННЫХ ТЕХНОЛОГИЙ И ПОДГОТОВКИ СБОРНЫХ КОМАНД МОСКОМСПОРТА

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ПО ВОПРОСАМ СПОРТИВНОЙ НАУКИ В ДЕТСКО-ЮНОШЕСКОМ СПОРТЕ И СПОРТЕ ВЫСШИХ ДОСТИЖЕНИЙ

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RELATIONSHIP BETWEEN ROTATIONAL INERTIA OF THE UPPER LIMBS AND LATENCY PERIOD IN THE SIMPLE FAST SENSOR MOTOR REACTIONS OF YOUNG ADULTS

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Introduction

One of the components of this response involves the latent period of simple sensor-motor reaction that is often viewed to be the result of integrative brain function [Bernstein,1967]. The influence of the motor component in the implementation of a simple motor response and reaction time, noted by the abovementioned authors, is Associated mainly with the type of nervous system rather than biomechanical and anthropometric characteristics of participants.. The period of muscular mechanical contraction is an important element which may delay reaction time [Jiménez-Jiménez et al.,2011] and according to Bernstein [Bernstein,1967] theory there is no simple linkage between motor neuronal output and movement. This theory implies that limb shape and current physical properties of contracted musculature distort motor output. It is also known that motor output involves inertial forces, which often impede the implementation of movement [Enoka,1994; Loeb, 1985, Murray et al., 1995]. These forces, in turn, depend on the mass and length of the driving segments, as well as the localization of the centers of mass of the reacting kinematic chain [Bernstein,1967] . Masses and lengths of reacting segments may affect reaction time [Chu, 1989; Gutnik, et al, 2001, Mignardot, et al.,2010, Samaras, 2007, Williams et al.,2008]. From a biomechanical perspective the masses and lengths of the reacting segments represent their inertial features and should be treated as peripheral elements of the motor system [Lieber, 2002]. Specifically, a relationship to rotational inertia can be considered, because all movement in the joints is rotary. Some authors studied the influence of rotational inertia of the reacting segments on the duration of motor reaction. For example, Anson [Anson, 1989] artificially increased the weight of the proximal and distal segments of tested limbs. He found some delay in reaction time corresponding with increasing rotational inertia of the reacting segment and vice versa. The main shortcoming of his study was that the experimental gravitational conditions for the test were very artificial and the motor program(s) selected for this new motor action had not been properly adapted to the new environmental force conditions.

Other researchers have increasingly paid attention only to the length of the limbs or total body height [Chu, 1989, Samaras,2007]. They concluded that participants with short stature and relatively short upper limbs react to simple stimuli more quickly, and vice versa. However, it must be remembered that these data are indirectly related to the inertial features of the upper extremities, because their lengths may only partially reflect these features. Some researchers noted that people with higher mass had longer reaction time, but explanations of their results were linked to only purely neural factors, such as distortion of sensory and proprioceptive signals [Mignardot et al, 2010,□Williams et al., 2008].

The aim of our study was to examine the dependence of reaction time on the moment of inertia of the limbs of participants during adduction of the forearm and hand. In contrast to Anson's [Anson, 1989] study, our research involved a large array of participants of both genders with the same age. This approach offers two advantages; the opportunity to compare the inertial characteristics of a large number of participants, and, to avoid artificial loading of their segments and, in turn, exclude adaptive respond of participants.

Methods

Participants

Five hundred and sixty six healthy students from 50 Moscow high schools (274 boys and 292 girls; aged 16-17 years) were involved in the study. None of the participants had outstanding athletic achievements.

Preliminary measurement of basic anthropometric parameters of the participants.

Standard anthropometrical methods for measuring height and body mass were used (with accuracy ± 0.5cm and ± 0.1kg respectively). Calculations of moments of rotational inertia used well known regression equations, separately for hand and forearm [Chaffin, 1999]. Afterward these data were averaged. Also, we measured the greatest and smallest circumferences of both forearms as well as their length from acromion to styloid process, as recommended [Malina & Buschang, 1984].

The Main Experiment.

The study of the latent period of simple sensor-motor reaction was performed using a specific instrument called a computer movement meter ("KMM") produced by the company INTOKS (St. Petersburg), Registration Certificate Number 29/03041202/5085-03 April 11, 2003. The accuracy of the time measurement of the simple sensor-motor reaction was 1ms.

Procedure

The participant was seated in a comfortable chair, while his/her hand rested on a special handle and lever, which, in turn, was able to revolve around a vertical axis. The fulcrum of the rotating segment was treated as the upper third of the forearm. In this position the forearm and wrist could perform abduction and adduction.

Mechanical resistance to rotational movement of the forearm was negligible and therefore ignored in the calculations. Initially, the lever with forearm and wrist resting on it was fixed on the zero position by electromagnetic arresters. Participants were instructed to focus on a cross in the centre of the screen, and to adduct the handle of the lever with their forearm and wrist as quickly as possible in response to visual signals started at random intervals (4–8 seconds. The visual signals (vivid light) were slightly peripheral to the central visual field, in order to potentially speed up sensor-motor reaction [Ando et al., 2002]. At the instant the light was switched on the electromagnetic arresters were simultaneously deactivated and the lever was able to move freely.

The latent period of the motor response, reaction time, was measured from the moment the light was switched on until the angular displacement of the forearm and lever was one degree as recorded by a computer. The participants were not limited in the possible amplitude of translation of the lever. The study was performed for both dominant and subdominant hands. Each participant produced 16 signal evoked reactions with each hand. Training before the experiment included reaction for 10 visual stimuli which were randomly distributed in time. Experiments in which the participant began to move the lever before appearance of the stimulus, as well as the first three and last three values of reaction time were excluded from the total data set. The total number of experiments was (566 participants x 20 stimuli). Time of presentation of each consequent signal ranged from 4 to 10 seconds to avoid the formation of a conditioned reflex to time.

Analysis.

Treatment of the primary data

The total value of the rotational inertia (RI), of the hand and forearm was calculated for each participant. Then the average value ($RI_{average}$) and standard deviation (□□ were calculated, separately for groups of girls and boys. Lateral differences in the upper extremities during the RT test were not significant (P>0.05) and hence we united the data performed by dominant and subdominant hands in each group. Thus we studied two groups of people: males and females. Based on the results of the calculation of the group average and individual data of rotational inertia the male and female participants were divided into three subgroups. Subgroups of the males were: A) with the middle individual values of rotational inertia: $RI_{Middle} = RI_{average} \pm 0.5$ □ = 60.54 - 74.69kgcm^2; B) with high values - $RI_{high} > RI_{average} + 0.5$ □□ i.e. >74.69kgcm^2; and, C) with low values $RI_{Low} < RI_{average} - 0.5$ □, i.e <60.54kgcm^2 of rotational inertia. The female subgroups were, correspondingly: A) 49.34 - 59.25kgcm^2; B) >59.25kgcm^2; and C) <49.34kgcm^2. Thus 6 subgroups were formed. Then, for each selected subgroup the appropriate range of RT was identified and mean values of the latent period were calculated (for subgroup A, $RT_{average\ A}$; for subgroup B, $RT_{average\ B}$; for subgroup C, $RT_{average\ C}$).

Statistical calculations were used to test and compare between the student's groups. The Chi-square method was used for comparison of frequency distribution of particular ranges of latency periods in different subgroups. In addition the point bisserial coefficient of correlation was calculated.

The full range of reaction time data (separately for boys and girls) was divided into seven intervals. Interval 1 includes the results of RT below 125ms; interval 2, from 126 to 150ms; interval 3, from 151 to 175ms; interval 4, from 176 to 200ms; interval 5, from 201 to 225ms; interval 6, from 226 to 250ms; and interval 7, more than 250ms. The Chi square test was used to compare the distribution between selected subgroups of males and females and also between equivalent subgroups of males and females.

Results

The main results of the research are presented in Table. It was established that the average value of rotational inertia of the total group of young males, was significantly higher than that of the females (P<0.001)

Table 1

Participants	Total group	Subgroup A	Subgroup B	Subgroup C
Males	N = 274	N = 143	N = 62	N = 69
RI $_{Average}$±□ (kgcm^2)	67.61 ± 14.15	67.35 ± 9.46	81.98 ± 14.09	54.68 ± 8.98
RT $_{Average}$ ±□ (ms)	0.153 ± 0.036	0.151 ± 0.028	0.169 ± 0.048	0.140 ± 0.029
Females	N = 292	N = 129	N = 69	N = 94
RI $_{Average}$±□ (kgcm^2)	54.30 ± 9.91	54.60 ± 7.26	64.47 ± 9.08	46.23 ± 5.90
RT $_{Average}$ ±□ (ms)	0.162 ± 0.034	0.160 ± 0.032	0.181 ± 0.039	0.149 ± 0.026

It was found that the RT strongly depended on the selected group. The highest values of RT occurred in subgroup B, the lowest in subgroup C (See Table). This pattern was apparent in both male and female groups. The differences between subgroups B and C, with high and low magnitude of rotational inertia respectively, were significant (up to 17.16% in male and 17.68% in female groups; P<0.001). Using the Chi square test we found significant differences in distribution of reaction times produced by equivalent male and female subgroups

In both male and female groups we found significant differences in distributions of RT data between all subgroups A, B and C. There was a marked difference in the number of participants in different subgroups reacting to visual stimuli very quickly and very slowly, as is illustrated in Table 3; 33.33% males and 19.15% females from group C reacted in a very fast way with RT less than 125ms. Participants from group B demonstrated very delayed reaction times; 21% males and 30.4% females demonstrated reaction time more than 200ms . The male and female participants of subgroup B have different RT modal intervals; 126-150 ms and 151-175ms respectively.

The relationship between subgroups containing people with different values of rotational inertia and their produced RT data was indicated by the value of point-bisserial correlation coefficients which were; 0.58 (comparing subgroups A and B), 0.46 (between subgroups A and C), and 0.72 (comparing subgroups B and C).

Discussion

The main objective of this research was to examine a relationship between time of simple motor reaction and magnitude of rotational inertia of the reacting segment, which may partly represent the integrative morphometric features of the human body. As was mentioned previously all our participants were recruited from 50 Moscow high schools, with approximately the same learning and physical environment.

Our results of RT are close to the results received by other authors for young healthy individuals [Brebner, & Welford, 1980; Parekh et al., 2004, Welford, 1980]. This outcome indicates the validity of the chosen method of researching the latent period.

We united the data of RT of both hands in one pool because we did not record significant group differences in total RT between left and right-sided actions. This finding can be explained by the fact that this motor response involved relatively proximal segments of upper extremities, whose muscles have bilateral innervations, from both the left and right hemispheres [Brinkman & Kuypers, 1972]. Three subgroups were selected within male and female groups on the basis of the values of their rotational inertia: one subgroup (A) with the middle range of RI, others with high (B) and low(C) ranges of RI. The same approach was used in our recent work [Skurvydas et al., 2009].

We tested the hypothesis that greater values of rotational inertia increase RT. The fact that participants having higher indices of rotational inertia of forearm and wrist reacted more slowly can be explained by the influence of inertial forces impeding the rotational acceleration of the hands (forearms and hands) at the beginning the movement. In our case, the participant had to make a very brief adduction around the vertical axis passing through the elbow of the participant.

It is well known that the latency period of simple sensor motor reactions is based on perceptual functions, decision making and motor performance [Schmidt & Lee,1999; Margill, 1988] and also depends upon the kinetic and kinematic properties of reacting segments [Enoka, 1985, Chu, 1989, Chaffin et al, 1999]. Since in our case, the participants were focused only on rapid movement in a predetermined direction where no accuracy was required we can suggest a low level of complexity for this kind of motor reaction [Schmidt & Lee, 1999]. This kind of movement requires more primitive programs that significantly reduce the time of decision making. Thus we restricted the scope of our research to find out the influence of the value of rotational inertia of segments on reaction time. During the experiment participants adducted their forearms over a very short distance in a constant direction. In other words, the realized motor reaction in our case appeared as a short jerk without any additional precise component. We classify this motion as a jerk because it was organized mainly by only one, relatively weak pronator teres muscle [Neumann, 2010], was lasting a very short time and had the aim to shift the essential mass of the segment. For this kind of reaction the role of inertial resistive forces became more influential. For this purpose, the central nervous system in a short period of time had to implement the recruitment of a large number of fibers of the muscle. If the segment had a greater mass and consequently greater rotational inertia, the recruitment of a greater number of muscle fibers required a longer period of time. Longer RT may be due to an additional period needed for increasing the number of active motor units and increasing their firing rate to optimize the tension generated, that is, spatial and temporal recruitment [Lieber,2002].

Results of other authors also support our hypothesis about influences of RI or its derivatives increasing reaction time [Skurvydas et al., 2009, Anson, 1982]. The NASA [NASA-STD-3000, 1995] report states that the time required to move an object in microgravity increases as the mass of the object increases.. Eckner and colleagues [Eckner ewt al.,2010] reported that the reaction times of football players averaged 0.203s when determined with a simple falling meter stick, but was 0.268s when measured with a computer, probably because the reacting segment had a different mass.

It was interesting that the pattern of relationship between RI and RT appeared separately within male and female groups but did not appear in comparison between males and females. As we can see males in different subgroups had greater RI indices; why in this case did females not react faster than males and why was the duration of the latent period in females significantly higher compared to equivalent groups of males?

It is known from the literature that males have faster reaction times than females, and this feature is not altered by training [Agúndez, 2011, Dane &. Erzurumluoglu, 2003; Welford, 1980, Adam et al, 1999, Der et al., 2006]. The male advantage in terms of shorter RT is also greater when using visual stimuli [Spierer et al., 2010]. In our case, this relationship manifested only in relation to subgroups A and C, and did not appear in group B. Group B of the girls reacted more slowly in terms of the data presented only in the modal interval. We suggest that it could be due to the difference in specific physiological and morphometrical organization of muscle systems in both genders. Males in the end of puberty have greater power output of skeletal muscles, and greater percentage of fast twitch fibers than females [Temfemo et al.,2009]. Thus males, even with a greater RI of the reacting segment initially, have greater muscle power to get this segment to react.

Our results indicate that rotational inertia is an important biomechanical characteristic of reacting upper extremities of participants and provides an essential component of reaction time. Rotational inertia should be considered when determining the latent period of sensor-motor reactions under different conditions.

Conclusions

1. A significant factor influencing reaction time is rotational inertia of the reacting segment. Individuals with high RI have a significant delay in RT in comparison to persons having low RI values. This dependence was observed equally in males and females.
2. The fact that males had a shorter latent period than females can be explained by the fact that the power of their muscles, which move the reacting segments, is greater.
3. In all investigations which study RT the individual value of RI should be considered. The role of RI increases markedly in cases where it is necessary to compare RT of participants that belong to different somatic groups.

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