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ORIGINAL ARTICLE

# Selected components of physical fitness in rhythmic and artistic youth gymnast

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## Abstract

**Purpose** Rhythmic (RG) and artistic gymnastics (AG) are very popular female sports. These two disciplines share some common points but, at the same time, they display some relevant differences in terms of physical and technical characteristics. The aim of this study was as follows: (1) to clarify how gymnastic training background over the years could lead to the development and motor learning of the motor skills and (2) to highlight differences of conditional skills achieved by RG and AG athletes.

**Methods** For these aims, 45 athletes were selected, belonging to three balanced groups: promotional (PG, $n = 15$), RG ($n = 15$), and AG ($n = 15$). Participants were tested for joints mobility, balance, explosive strength, speed, and endurance tests.

**Results** Statistical analysis showed a good test–retest reliability of the measurements (ICC > 0.870) and some significant differences between PG, RG, and AG. RG showed higher values in joint mobility tests (coxo-femoral mobility, 166.7 ± 6.3°; sit and reach, 20.5 ± 1.9 cm; and scapulo-humeral mobility, 45.5 ± 4.4 cm) with respect to AG, while AG showed higher values in endurance (1626.7 ± 7.4 m), balance (4.33 ± 1.35 n/60 s), and explosive strength (164.1 ± 11.6 cm) compared to RG ($p < 0.05$).

**Conclusion** RG and AG seem to be effective in enhancing different and sport-specific physical fitness and conditioning. RG enables, indeed, to develop more joints mobility whereas AG improves more strength, balance, and endurance. However, given the small sample size employed, these results should be replicated by further studies utilizing larger samples.

**Keywords** Assessment · Expertise · Gymnastics · High performance · Training process

## Introduction

The available body of scientific evidence well supports the statement that regularly practicing physical activity provides fundamental health benefits for children and youth [1] especially in the musculoskeletal [2], cardiovascular [3], metabolic [4], immunologic [5], and cognitive [5] domains. According to the World Health Organization (WHO) guidelines, children, and youth aged 5–17 years should perform at least 60 min of moderate to vigorous intensity physical activity daily [1].

Physical activity in childhood was considered to be crucial for the development and acquirement of correct movement patterns in most youth sports—that is to say, those sports where a performance peak is achieved at a relatively young age [6]. Artistic (AG) and rhythmic gymnastics (RG) are age-dependent [7]. Gymnastics training develops, indeed, strength, flexibility, concentration,

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balance, grace, and speed, among others, in young athletes [8]. Both RG and AG are international sports, recognized by the Italian Federation of Gymnastics (FIG). Both these two forms of gymnastics share many similar attributes but differ in terms of events, rules, and style [9]. For females, AG events include performances on different equipment (e.g., vault, uneven bars, balance beam, and floor), while RG events are all performed on the same equipment—a padded floor, that can vary according to the specific support utilized (e.g. rope, hoop, ball, clubs, and ribbon).

It is important that girls and young women participate in sports and develop skills that promote lifelong athletic participation, because of the psychological, sociologic [10], and physiological benefits associated with exercise [11].

Regular trainings in these sports start at the age of 6–7 years. One of the reasons is that the age group ranging from 7 to 11 years old is considered to be a sensitive period for flexibility development [7]. Another reason is probably the intention to start to apply deliberate practice [12] around the age of 10 years old, somewhat before the optimal age for improving power and strength [7]. This age group goes from 12 to 17 years [13] in order to reach peak strength and peak performance of all required skills around the age of 16 [14]. Investing in deliberate practice during childhood and early adolescence becomes vital for achieving the peak performances before adulthood [15]. Within this deliberate practice, physical fitness represents an important factor for success and it provides the basis for the technical skill development. A higher physical fitness level is often related to better performances [16].

Considering the differences of these two sports in terms of events and performances, it is clearly expected that performed movements and demands towards competitors differ as well. Complex tumbling and acrobatics generally characterize women artistic gymnastics. This requires high levels of upper and lower body strength, power, flexibility, and muscular endurance, combined with speed and coordination [17]. Rhythmic gymnastics is mainly characterized by grace presented through the performance of basic acrobatic elements, variety of dance elements and movements, all performed with different props which need to be in constant motion. Generally, rhythmic gymnastics performances require a greater level of flexibility, rhythm, legs strength, endurance, coordination, agility, and balance [18]. In particular, a good compromise between strength and flexibility has been identified as the most contributing factor to performance [19].

Therefore, the aim of this study was to demonstrate how gymnastic training background over the years could modify and develop the physical fitness and to clarify the differences between motor skills achieved by the athletes of artistic and rhythmic gymnastics.

## Materials and methods

### Participants

The present study involved 45 volunteer female subjects, aged between 10 and 12 years, all belonging to the same sports club. The sample was divided into three groups: promotional (PG), rhythmic gymnastics (RG), and artistic gymnastics (AG) group. RG and AG were the case groups, whereas PG acted as control. PG group had 15 subjects (mean age $11.1 \pm 0.9$ years; mean height $141.1 \pm 7.8$ cm; mean weight $38.3 \pm 5.4$ kg; mean BMI $18.9 \pm 1.8$ kg/m$^2$) with a training experience of $5.8 \pm 0.9$ months and 3 h of training per week. RG group had 15 subjects (mean age $11.1 \pm 1.0$ years; mean height $147.0 \pm 10.5$ cm; mean weight $34.3 \pm 6.3$ kg; mean BMI $15.7 \pm 0.9$ kg/m$^2$) with a training experience of $45.6 \pm 8.0$ months and 9 h of training per week. AG group had 15 subjects (mean age $11.2 \pm 0.8$ years; mean height $144.9 \pm 9.5$ cm; mean weight $36.7 \pm 5.2$ kg; mean BMI $17.4 \pm 0.9$ kg/m$^2$) with a training experience of $51.5 \pm 7.4$ months and 9 h of training per week.

The inclusion criteria for the study participations were as follows: (i) absence of any kind of ankle injury or having undergone/undergoing surgery, (ii) no history during the 3 months preceding the test of neuromuscular disease, vertigo, or any uncorrected visual problems, and (iii) no use of sedative medications or analgesic drugs. Subjects not meeting with these criteria were excluded from the study.

Before testing, written informed consent was obtained from the parents/legal guardians of participants (because of their minor age), after they were given a thorough explanation of the purpose, benefits, and potential risks of participating in the study. The protocol conformed to internationally accepted policy statements regarding the use of human participants, in accordance with the Declaration of Helsinki, and was approved by the University's ethics committee.

#### Findings reporting

The present study follows the "Strengthening the Reporting of Observational Studies in Epidemiology" (STROBE) Statement guidelines for reporting observational studies [20].

### Procedures

The data collection was carried out through field-based motor tests. Tests were performed in May 2017 in South Italy. All the tests were performed in the gym except for the Coooper's test that was performed on the track and field.

Data were obtained for (i) joint mobility of the dorso-lumbar hinge and the posterior muscular chain by means of the "sit and reach test" (as a measure of the flexibility of the lower back and hamstring muscles), (ii) coxo-femural mobility by means of the "abduction test of the hips" (performed by actively abducting the hips), (iii) scapulo-humeral mobility by means of the "wand test" (as a measure of the flexibility of the scapula-humeral muscles), (iv) balance by means of the "flamingo test" (performed standing on one leg), (v) explosive strength of the lower limbs by means of the "standstill long jump" (performing a long jump starting from standstill), (vi) speed by means of the "10 m test" (as a measure of the gait speed), and (vii) endurance by means of the "Cooper's test" (a 12-min run aerobic fitness test, which provides an estimate of $VO_{2max}$).

Each athlete was assessed at the same day and the test sequence was the same of the previous list. Each subject respected 3 days of rest between last training session and the test day. All the subjects have been previously instructed on the tests and each subject performed a simulation of each test 2 weeks before the official test day. After 1 week, each test was repeated to assess the reliability of the measures.

### Statistical analysis

The data obtained from the field-based motor tests were processed and calculated as mean and standard deviation (SD). The distribution and presence of abnormal values among the data have been verified before starting any parametric analysis, using the Shapiro–Wilk's test for normality of data distribution. This test was preferred to other tests because of the small sample size employed. Multivariate regressions and generalized linear models were performed to shed light on the determinants of differences between RG and AG groups, utilizing PG as controls. More in details, these analyses were carried out in order to compare different variables and to understand how each physical parameter was influenced by training experience, BMI, age, group, and hours of weekly training. Furthermore, the Pearson coefficient was used to assess correlations between the measured parameters. The statistical correlation tests were performed on the whole sample in order to understand the relationship between different physical skills. Intra-class correlation coefficient (ICC) was used to assess the reliability of the measurements [21]. For each comparison between each group, analysis of variance (ANOVA) was used. Effect sizes (ES) were also computed calculating the Cohen's *d* (the difference between the means of two groups divided by the pooled standard deviation) [22]. ES up to 0.20 was considered small, up to 0.50 medium, up to 0.80 large, and exceeding 0.80 very large. An a priori sample size power analysis computed a sample of 13 subjects per group to capture a pairwise medium ES with an alpha error probability of 0.05 and a power set at 0.80. A post hoc sample size power analysis showed that, based on the obtained ES, the recruited sample was adequate, in that ESs were captured with an alpha error probability of 0.05 and a power of 0.95 (a sample in the range of 3–10 subjects per group would have been enough). All statistical analyses were conducted using the commercial software "Statistical Package for Social Sciences" (SPSS, version 23.0.0—IBM Corporation, Armonk, NY, USA). Significance level was set at $p < 0.05$.

## Results

Test–retest showed a good reliability (ICC > 0.870). Differences between all measured variables for subsamples of PG, AG, and RG were analyzed at the significance level of $p < 0.05$ (Table 1). There are no significant differences for age, height, and weight, but there is a significant difference between subsamples in BMI. Further, a significant difference ($p < 0.001$) was found within the results of the various motor tests and within the years of training. In particular, better values were found in AG, considering the Cooper's endurance test (1626.7 ± 7.4 m), the standstill long jump test (164.1 ± 11.6 cm) and the Flamingo test (4.33 ± 1.35 n/60 s). Similarly, RG subsample showed higher values for articular mobility tests, such as coxo-femoral mobility (166.7 ± 6.3°), sit and reach (20.5 ± 1.9 cm), and scapulo-humeral mobility (45.5 ± 4.4 cm). In the 10 m test, PG subsample showed the worst value, while RG and AG were very similar although RG group showed a better result (2.30 ± 0.18 s) with respect to the AG group. Moderate to high significant correlation was found between the motor tests results (Table 2).

The strongest significant correlation was found between the coxo-femoral mobility and the sit and reach test ($r = 0.826$). Results of the multivariate regression are presented in Table 3.

Age seems to significantly impact on the 10 m speed and the Cooper's tests. The coxo-femoral mobility and the standstill long jump test performance were significantly influenced by the type of training (PG, RG, and AG). Finally, the Cooper's test, the coxo-femural mobility, and the scapulo-humeral mobility performance were significantly affected by the hours of weekly training.

## Discussion

The aim of this research was double: the first was to demonstrate how prolonged activity over the years could develop the motor skills of each participant; the second aim was to provide the evidences between two similar sports such as rhythmic and artistic gymnastics.

**Table 1** Sample characteristics broken down according to type of training

| Variables | PG | | RG | | AG | | *p* value | ES | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | | RG vs PG | AG vs PG | RG vs AG |
| Age (years) | 11.1 | 0.9 | 11.1 | 1.0 | 11.2 | 0.8 | 0.891 | 0.00 | 0.12 | 0.11 |
| Height (cm) | 141.1 | 7.8 | 147.0 | 10.5 | 144.9 | 9.5 | 0.231 | 0.64 | 0.44 | 0.21 |
| Weight (kg) | 38.3 | 5.4 | 34.3 | 6.3 | 36.7 | 5.2 | 0.158 | 0.68 | 0.30 | 0.42 |
| BMI (kg/m$^2$) | 18.9 | 1.8 | 15.7 | 0.9 | 17.4 | 0.9 | < 0.001 | 2.25 | 1.05 | 1.89 |
| Hours of training per week | 3.0 | – | 9.0 | – | 9.0 | – | – | – | – | – |
| Training experience (months) | 5.8 | 0.9 | 45.6 | 8.0 | 51.5 | 7.4 | < 0.001 | 6.99 | 8.67 | 0.77 |
| Cooper test (m) | 1280.7 | 104.0 | 1566.0 | 83.0 | 1626.7 | 74.0 | < 0.001 | 3.03 | 3.83 | 0.77 |
| Coxo-femoral mobility (°) | 132.1 | 9.0 | 166.7 | 6.3 | 152.1 | 5.2 | < 0.001 | 4.45 | 2.72 | 2.53 |
| 10 m speed (s) | 2.57 | 0.15 | 2.30 | 0.18 | 2.35 | 0.13 | < 0.001 | 1.63 | 1.57 | 0.32 |
| Flamingo test (n/60 s) | 8.53 | 2.20 | 5.07 | 1.49 | 4.33 | 1.35 | < 0.001 | 1.84 | 2.30 | 0.52 |
| Sit and reach test (cm) | 13.3 | 4.5 | 20.5 | 1.9 | 18.1 | 2.4 | < 0.001 | 2.08 | 1.33 | 1.11 |
| Standstill long jump (cm) | 125.9 | 15.3 | 135.5 | 7.9 | 164.1 | 11.6 | < 0.001 | 0.79 | 2.81 | 2.88 |
| Scapulo-humeral mobility (cm) | 67.7 | 5.7 | 45.5 | 4.4 | 51.3 | 8.9 | < 0.001 | 4.36 | 2.19 | 0.83 |

*AG* artistic gymnastics group, *BMI* body mass index, *ES* effect size, *PG* promotional group, *RG* rhythmic gymnastics group

**Table 2** Correlation between the different tests examined

| | 10 m speed | Cooper's test | Coxo-femoral mobility | Flamingo test | Sit and reach test | Standstill long Jump |
|---|---|---|---|---|---|---|
| Cooper's test | | | | | | |
| Correlation coefficient | – 0.635 | | | | | |
| *p* value | < 0.001 | | | | | |
| Coxo-femoral mobility | | | | | | |
| Correlation coefficient | – 0.540 | 0.687 | | | | |
| *p* value | 0.001 | < 0.001 | | | | |
| Flamingo test | | | | | | |
| Correlation coefficient | 0.497 | – 0.692 | – 0.581 | | | |
| *p* value | 0.005 | < 0.001 | < 0.001 | | | |
| Sit and reach test | | | | | | |
| Correlation coefficient | – 0.512 | 0.621 | 0.826 | – 0.469 | | |
| *p* value | 0.003 | < 0.001 | < 0.001 | 0.012 | | |
| Standstill long jump | | | | | | |
| Correlation coefficient | – 0.441 | 0.639 | 0.257 | – 0.542 | 0.270 | |
| *p* value | 0.024 | < 0.001 | 0.088 | 0.001 | 0.072 | |
| Scapulo-humeral mobility | | | | | | |
| Correlation coefficient | 0.487 | – 0.629 | – 0.764 | 0.624 | – 0.643 | – 0.217 |
| *p* value | 0.007 | < 0.001 | < 0.001 | < 0.001 | 0.001 | 0.152 |

*AG* artistic gymnastics group, *BMI* body mass index, *RG* rhythmic gymnastics group, *PG* promotional group

In Cooper test, coxo-femoral mobility, and scapulo-humeral mobility, it is possible to observe how hours of training per week are closely related to the results obtained in the motor tests. Those results highlight the purpose of our study and demonstrate that training improves motor abilities. Good motor skills are considered important for children's physical, social, and psychological development and may even be the foundation for an active lifestyle, since several studies have shown a positive association between good motor skills and higher levels of physical activity [23]. Consequently, there is evidence of many health benefits to be gained from an improvement in motor skills [6].

A significant gap is present between the PG and the competitive athletes (RG and AG) for the average values of BMI and all field-based motor tests. Probably, the RG lowest values of BMI are responsible for obtained results; however,

**Table 3** Multivariate regressions and generalized linear models

| Independent variables | Coefficient | Standard error | $r_{partial}$ | $T$ | $p$ |
|---|---|---|---|---|---|
| 10 m speed (s): $R^2 = 0.71$, adapted $R^2 = 0.67$ | | | | | |
| (Constant) | 4.000 | | | | |
| Training experience (months) | −0.003 | 0.003 | −0.154 | −0.975 | 0.335 |
| BMI | −0.007 | 0.014 | −0.084 | −0.527 | 0.601 |
| Age (years) | −0.111 | 0.023 | −0.614 | −4.854 | < 0.001 |
| Type of training | 0.093 | 0.048 | 0.297 | 1.939 | 0.059 |
| Hours of weekly training | −0.044 | 0.027 | −0.255 | −1.646 | 0.107 |
| Cooper's test (m): $R^2 = 0.81$, adapted $R^2 = 0.79$ | | | | | |
| (Constant) | 285.184 | | | | |
| Training experience (months) | −3.519 | 2.382 | −0.230 | −1.477 | 0.147 |
| BMI | 10.159 | 10.114 | 0.158 | 1.004 | 0.321 |
| Age (years) | 51.147 | 16.747 | 0.439 | 3.054 | 0.004 |
| Type of training | 57.140 | 35.184 | 0.251 | 1.624 | 0.112 |
| Hours of weekly training | 66.836 | 19.506 | 0.481 | 3.426 | 0.001 |
| Coxo-femoral mobility (°): $R^2 = 0.84$, adapted $R^2 = 0.82$ | | | | | |
| (Constant) | 110.945 | | | | |
| Training experience (months) | 0.029 | 0.201 | 0.0234 | 0.146 | 0.885 |
| BMI | 1.583 | 0.852 | 0.285 | 1.857 | 0.071 |
| Age (years) | −1.775 | 1.412 | −0.197 | −1.257 | 0.216 |
| Type of training | −17.305 | 2.965 | −0.683 | −5.836 | < 0.001 |
| Hours of weekly training | 9.318 | 1.644 | 0.672 | 5.668 | < 0.001 |
| Flamingo test (times): $R^2 = 0.60$, adapted $R^2 = 0.54$ | | | | | |
| (Constant) | 1.808 | | | | |
| Training experience (months) | −0.069 | 0.050 | −0.218 | −1.396 | 0.171 |
| BMI | 0.372 | 0.210 | 0.272 | 1.767 | 0.085 |
| Age (years) | 0.030 | 0.348 | 0.014 | 0.087 | 0.931 |
| Type of training | −0.966 | 0.732 | -0.207 | -1.321 | 0.194 |
| Hours of weekly training | 0.242 | 0.406 | 0.095 | 0.597 | 0.554 |
| Sit and reach test (cm): $R^2 = 0.49$, adapted $R^2 = 0.43$ | | | | | |
| (Constant) | 12.139 | | | | |
| Training experience (months) | 0.036 | 0.096 | 0.059 | 0.369 | 0.714 |
| BMI | 0.163 | 0.405 | 0.064 | 0.401 | 0.690 |
| Age (years) | −0.343 | 0.671 | −0.082 | −0.511 | 0.612 |
| Type of training | −2.839 | 1.410 | −0.307 | −2.014 | 0.051 |
| Hours of weekly training | 1.516 | 0.782 | 0.297 | 1.939 | 0.060 |
| Standstill long jump: $R^2 = 0.74$, adapted $R^2 = 0.71$ | | | | | |
| (Constant) | 28.067 | | | | |
| Training experience (months) | 0.288 | 0.321 | 0.142 | 0.896 | 0.376 |
| BMI | 2.198 | 1.362 | 0.250 | 1.613 | 0.115 |
| Age (years) | 3.675 | 2.256 | 0.252 | 1.629 | 0.111 |
| Type of training | 22.670 | 4.739 | 0.608 | 4.784 | < 0.001 |
| Hours of weekly training | −2.905 | 2.627 | −0.174 | −1.106 | 0.276 |
| Scapulo-humeral mobility (cm): $R^2 = 0.71$, adapted $R^2 = 0.67$ | | | | | |
| (Constant) | 39.208 | | | | |
| Training experience (months) | −0.052 | 0.194 | −0.043 | −0.269 | 0.789 |
| BMI | 0.902 | 0.822 | 0.173 | 1.097 | 0.279 |
| Age (years) | 1.636 | 1.360 | 0.189 | 1.203 | 0.236 |
| Type of training | 4.415 | 2.858 | 0.240 | 1.545 | 0.131 |
| Hours of weekly training | −3.605 | 1.584 | −0.342 | −2.276 | 0.028 |

*AG* artistic gymnastics group, *BMI* body mass index, *RG* rhythmic gymnastics group, *PG* promotional group this needs to be confirmed in other analysis. Differences are present also for RG and AG because of the intrinsic difference of sport-specific stimulus and relative adaptations. RG athletes seem to be better than AG athletes in lower limb mobility tasks such as coxo-femural mobility and sit and reach test, while AG athletes are better than RG athletes in endurance, strength and power task, balance, and upper limb mobility. Only the speed seems to be very similar with only 0.05 s of difference in favour of the RG athletes.

These differences strictly depend on the physical adaptation of the athletes to the sport-specific training load. In fact, the artistic gymnastics aim is to develop exercises on the ground for competition lasting 1′30″ with diagonals made of continuous technical elements, which require aerobic resistance. In the rhythmic group, instead, the competition exercises are less dynamic, with considerable changes of rhythm [24]. The balance performance, as well as the endurance, is better in AG athletes because of the similarity of the Flamingo test with sport-specific movements of artistic gymnastics. In fact, during the training on the beam, the AG athletes perform jumps and evolution on a surface 10 cm wide, unlike the RG athletes, who work on the entire surface of the ground [25]. Moreover, the training of AG athletes provides a higher stimulus on strength and power with respect to the RG athletes training. In artistic gymnastics, there are various evolutions in flight and in a single jump with different rotations on the different body axes [25]; this can explain the higher performance in standstill long jump for the AG with respect to the RG. Sport-specific adaptations are present also for the RG. In fact, this group showed better values for lower limb and trunk mobility. This kind of training is fundamental in rhythmic gymnastics because it allows reaching high degrees of articular excursion, which is used to perform positions of fluency and fundamental elements in the composition of the competition exercises.

The data fundamentally depend on the type of training: in fact, the RG works more on joint mobility and muscle lengthening while the AG works on strength and power to perform specific technical gestures in difficult balance conditions. This is in line with results of Vicente-Rodriguez et al. [26] that found recreational artistic gymnastic participation is associated with delayed pubertal development, enhanced physical fitness, muscle mass, and bone density in prepubertal girls, eliciting a higher osteogenic stimulus than rhythmic gymnastics. The deterioration of growth potential in female artistic gymnastic is also observed in Georgopoulos et al. [27]. According to these results, the training of artistic gymnastics should be based on exercises of both strength and endurance organized gradually by intensity, speed of execution, and number of repetitions and series, which affect the muscular districts in a balanced manner, left and right part, and upper and lower part of the body. Instead, the training of rhythmic gymnastics should be based on stretching and mobility according to the technical elements of the competition exercises, in order to achieve the best specific strength. One of the principal limitations of this study is the difference in terms of months of training expertise between the PG, RG, and AG groups. Although this value is not related to any performance in motor test, according to the multivariate regression, it should be better to compare in future studies some PG with the same time of training experience with respect to the competitive groups.

Finally, the data of this study confirm the previous literature on the centrality to train in a specific way in order to achieve a good physical condition; furthermore, it is clear the difference between the performances among the motor tests of the PG with respect to the two competitive groups RG and AG. The significant relationship between the amounts of hours of weekly training and the performance of some motor tests is a strong index of the necessity to improve physical training in order to achieve better physical results. In conclusion, we estimated the difference between the results achieved by the athletes of AG and RG highlighting strength, endurance, and balance more in the AG, and the articular mobility more in the RG.

## Conclusions

In conclusion, rhythmic and artistic gymnastics seem to be effective in enhancing different and sport-related physical skills and adaptations. Rhythmic gymnastics develops more joints mobility and artistic gymnastics develops more strength, balance, and endurance. Present results should be implemented by other studies involving bigger samples.

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### Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical approval** The protocol conformed to internationally accepted policy statements regarding the use of human participants, in accordance with the Declaration of Helsinki, and ethical approval was agreed by the ethical committee of the institution Novi Sad University.

**Informed consent** Informed consent was obtained from all the parents/legal guardians of participants (because of their minor age), after they were given a thorough explanation of the purpose, benefits, and potential risks of participating in the study.

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