



## VALIDITY OF THE DICKSON INDEX REGARDING PRIMARY SCHOOL PHYSICAL EDUCATION

original paper

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IHOR ZANEVSKYY, LYUDMYLA ZANEVSKA

Department of Informatics and Kinesiology, Lviv State University of Physical Culture, Lviv, Ukraine

### ABSTRACT

**Purpose.** The paper is dedicated to the problem of testing physical capacity in primary school with the use of the Ruffier-Dickson test. The research aimed to verify the Dickson index corrected for the children's age with the intention of usage in primary school physical education.

**Methods.** Four groups of healthy males – aged 6, 7, 8, and 18 years – were randomly selected, 30 participants in each. One way ANOVA, *t*-test for independent samples, and intra-correlation coefficient were used to evaluate the validity of the Dickson index for the original and age-corrected functions. It was assumed that Dickson index values should not depend upon age among healthy participants in normal physical capacity.

**Results.** Invalidity of the original Dickson index for 6–8-year-old children was shown, with a significant difference of their results from those of the adults ( $p < 0.001$ ). The use of the index formula corrected for the age of children gives no significant difference between all the groups ( $p = 0.817$ ) and a good level of validity, taking into consideration the corresponding intra-class correlation coefficient of 0.688. This conclusion is supported with *t*-test results ( $p = 0.915$ ), which show a rather good level of the test validity.

**Conclusions.** To guarantee the validity of the Dickson index, the results of heart rate measurements should be reduced proportionally to the ratio of a normal heart rate of the young patients' population to the normal heart rate in adults.

**Key words:** exercise test, heart rate, sports medicine, fitness

### Introduction

The Ruffier-Dickson test is used in sport medicine [1, 2] and in physical education [3] for heart rate estimation in healthy individuals [4]. It is recognised by the Ukrainian Ministry of Education and Science as an obligatory test in school physical education for all pupils of 6–18 years of age. On the basis of the test results, students are divided into 3 groups depending on their health level, and corresponding physical efforts for physical education lessons and out-of-school physical activity are ascribed [5].

Originally, the test was intended for evaluation of heart resistance to physical effort in adults [6, 7]. Because a normal resting heart rate in children is higher than in adults [8], the test shows understated results in school physical education; in particular, it is strongly

invalid for the small pupils of 6–8 years of age. For example, with the use of the original Dickson index, 40 healthy pupils aged 6 years were divided into 3 groups for the lessons of physical education with normal, reduced, and minimal physical effort as 1, 5, and 34 persons, respectively. Contrary, 40 healthy pupils aged 16 years in the same school were divided into the groups as 29, 10, and 1 person [5]. It is easy to notice an invalid division of the 6-year-olds and a valid division of the 16-year-olds.

Therefore, a Ruffier index formula corrected for the pupils' age was derived with the consideration of the difference between normal heart rate in children and adults [9]. A verification of the corrected index for the 6–8-year-old children showed an acceptable level of the test validity with this index model [10]. The Dickson index is less sensitive to the difference of the normal

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Correspondence address: Ihor Zanevskyy, Lviv State University of Physical Culture, Kostyushka 11, 79007 Lviv, Ukraine, e-mail: [izanevsky@ukr.net](mailto:izanevsky@ukr.net)

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heart rate in adults and children, but the validity of the test is not acceptable, as well as the original Ruffier index is not acceptable. Dickson derived his index intending it for males and females without any differences [6]. The index is valid for adults, but it is invalid for young patients [11]. This research aims to verify the Dickson index corrected for the children's age, intended for primary school physical education.

### Material and methods

The validity of the Dickson index was studied in the frames of concurrent validity that refers to the ability of a measurement device to vary directly with a measure of the same construct. It allows showing that a test is valid by comparing it with an already valid test [12]. The original Dickson index for adults [6] was recognised as valid because of many years of successful practice in sports medicine and physical education. The validity of the Dickson index corrected for the age of young patients [5] was evaluated by comparing its mean values calculated for good health and normal physical activity pupils with mean values calculated for good health and normal physical activity adults. The Dickson index values or the corresponding distribution into the levels of the body readiness to resist physical effort do not depend on the age of healthy participants with normal physical capacity.

### Participants

Each of the 4 study groups consisted of 30 males. The samples involved 6-, 7-, and 8-year-old pupils of the city primary school and 18–20-year-old students of the Polytechnic University. All the participants were healthy and maintained normal physical activity. The samples were selected randomly from the particular age populations with a purpose to compare the Dickson index values in its original and age-corrected forms.

### Measurements

The test consisted of 3 measurements of the heart rate: after 5-minute relax, immediately after physical effort (30 squats during 45 seconds), and then after a short (30-second) relax. The heart rate was measured manually as the pulse on a wrist. Numbers of beats over 15 seconds were noted and then multiplied by 4 to give the pulse value in beats per minute. According to the joint order of Ministry of Education and Science of Ukraine and Ministry of Health of Ukraine, the measurements were carried out by school medical special-

ists after corresponding instructions and training of subjects in the frames of the Ruffier-Dickson test [6]. The measurements were performed as a regular testing at the very beginning of the school/academic year (i.e. in September), near noon, in the medical rooms of corresponding primary and high schools.

### Procedure

The original Dickson index ( $I$ ) [6] was calculated with the following formula:

$$I = \frac{(P_1 - 70 + 2(P_2 - P_0))}{10} \quad (1)$$

where  $P_0$  is resting heart rate per minute,  $P_1$  is heart rate recalculated per minute just after the end of the effort,  $P_2$  is heart rate recalculated per minute just after the end of the short relax.

Overall, 7 levels of physical capacity according to the magnitude of the Dickson index are introduced. Five of them, which are defined as 'very good,' 'good,' 'average,' 'passable,' and 'bad,' are in the range of the index values between 0 and 10 ( $I = 0 \div 2 \div 4 \div 6 \div 8 \div 10$ ), and 2 intervals are open: for  $I < 0$ , the physical capacity is evaluated as 'excellent,' and for  $I > 10$  as 'very bad'.

The Dickson index adapted for children ( $I_c$ ) was calculated with the following formula [5]:

$$I_c = \frac{[P_1 + 2(P_2 - P_0)] \frac{P_a}{P_p} - 70}{10} \quad (2)$$

where  $P_a$  of  $70 \text{ min}^{-1}$  and  $P_p$  of 102, 98, and  $93 \text{ min}^{-1}$  are normal population heart rates at rest for adults ( $a$ ) and for young patients ( $p$ ) aged 6, 7, and 8 years, respectively.

### Statistical analysis

Shapiro-Wilk test was used to evaluate the probability of a normal distribution of the Dickson index values in the research groups. One way ANOVA and Student  $t$ -test served to compare the mean values of the index in the samples of different ages. The Dickson index validity was estimated with the  $t$ -test of difference between the adult group and each of the 3 pupil samples. The greater significance level shows the greater validity of the index. The validity of the index was estimated with the use of the intra-class correlation coefficient ( $ICC$ ) [13]:

$$ICC(1,k) = \frac{MS_W - MS_B}{MS_W} \quad (3)$$

where  $MS_W$  and  $MS_B$  are within- and between-group variations,  $k = 4$  is the number of groups. Confidence ( $q$ ) interval limits (with  $q = 1 - p$ ) for the validity coefficient estimated with the intra-class correlation model (equation 3) were estimated as follows:

$$1 - F_L^{-1} \text{ and } 1 - F_U^{-1} \quad (4)$$

where  $F_L = F_0/F_{p,n(k-1),n-1}$  and  $F_U = F_0F_{p,n-1,n(k-1)}$ ,  $F_0 = MS_W/MS_B$ ,  $p = 0.05$  is significance,  $n = 30$  is the number of subjects in each group.

**Ethical approval**

The research related to human use has been complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Scientific Board of Lviv State University of Physical Culture.

**Informed consent**

Informed consent has been obtained from all adult individuals included in this study and from the parents of all the 6–8-year-old participants.

**Results**

The statistics of the Dickson index values calculated with the original formula (equation 1) for all the 4 groups are collected in Table 1. In addition, the statistics of the Dickson index values for the 3 pupil groups calculated with the corrected formula are placed in the table with the round brackets. The Shapiro–Wilk ( $SW-W$ ) parameters (0.943–0.978,  $p$ : 0.112–0.820) showed a good similarity of distribution in each of the 4 groups with normal distribution. Therefore,

Table 1. Dickson index: original (corrected)

| Statistics  | Age (years) |            |            |       |
|-------------|-------------|------------|------------|-------|
|             | 6           | 7          | 8          | 18–20 |
| <i>M</i>    | 8.8 (3.9)   | 7.9 (3.7)  | 7.6 (4.0)  | 3.8   |
| <i>SD</i>   | 1.5 (1.1)   | 1.6 (1.1)  | 1.8 (1.4)  | 1.3   |
| <i>Max</i>  | 13.4 (7.0)  | 12.2 (6.7) | 11.0 (6.5) | 6.6   |
| <i>Min</i>  | 7.0 (2.6)   | 5.4 (1.9)  | 3.8 (1.1)  | 1.8   |
| <i>SW-W</i> | 0.971       | 0.959      | 0.978      | 0.943 |
| <i>p</i>    | 0.783       | 0.303      | 0.820      | 0.112 |

*M* – arithmetic mean, *SD* – standard deviation, *Max* – maximal, *Min* – minimal, *SW-W* – Shapiro–Wilk parameter, *p* – significance

the parametric statistics could be recognised as acceptable here.

The one way ANOVA results showed a significant difference ( $p < 0.001$ ) between the 4 groups regarding the original Dickson index mean values (Table 2), but the main difference was noticed between the children ( $M = 7.6 \pm 1.8 - 8.8 \pm 1.5$ , which means passable and bad physical capacity) and the adult group ( $M = 3.8 \pm 1.3$ , which means good physical capacity). The ANOVA results regarding the age-corrected Dickson index mean values did not show significant differences ( $p = 0.817$ ) between the 4 groups ( $M = 3.7 \pm 1.1 - 4.0 \pm 1.4$ , meaning good physical capacity) (Table 1). In addition, the relative part of the between-group variation for the original index model (60.4%) was rather greater than for the corrected index (0.8%).

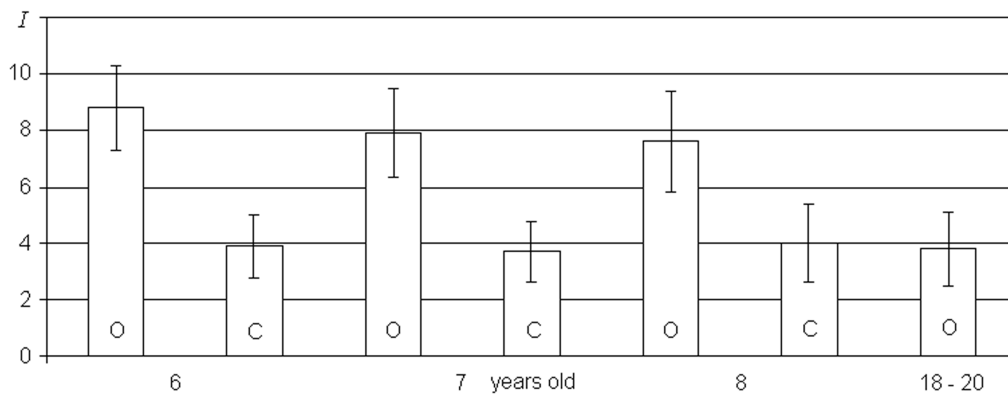
According to the results of the *t*-test, the difference between the adult group and each of the children groups regarding the original values of the index was strongly significant ( $p < 0.001$ ), resulting in the evaluation of the test as invalid for children (Figure 1). In turn, with the corrected Dickson index values, the *t*-test did not show any significant difference between the adult and children groups ( $p = 0.915$ ).

The results in the frames of the intra-class corre-

Table 2. ANOVA results of the Dickson index: original (corrected)

| Source of variation | SS               | df  | MS               | F               | p                | Q (%)          |
|---------------------|------------------|-----|------------------|-----------------|------------------|----------------|
| Between age groups  | 441.7<br>(1.4)   | 3   | 147.2<br>(0.472) | 58.9<br>(0.312) | 0.000<br>(0.817) | 60.4<br>(0.8)  |
| Within groups       | 289.8<br>(175.7) | 116 | 2.50<br>(1.51)   |                 |                  | 39.6<br>(99.2) |
| Total               | 731.5<br>(177.1) | 119 |                  |                 |                  | 100.0          |

SS – sum of squares, *df* – degree of freedom, *MS* – variance, *F* – Fisher-Snedecor statistics, *p* – significance, *Q* – relative part of the total variation



O – values calculated with the original Dickson formula (equation 1), C – values calculated with the formula corrected for age (equation 2)

Figure 1. Dickson index ( $M \pm SD$ )

lation model using equations 3 and 4 were calculated as follows:  $ICC = 0.688$ ,  $F_0 = 3.210$ , and  $p(F_0) = 0.974$ . Interval limits (on the  $q = 95\%$  level of confidence) were calculated as 0.465 and 0.804 ( $F_L = 1.869$ ,  $F_{0.05, 90, 29} = 1.717$ ,  $F_U = 5.115$ ,  $F_{0.05, 29, 90} = 1.593$ ).

## Discussion

The aim of the research was to verify a model of the Dickson index corrected for the children age with the intention to determine its validity in primary school physical education. In one of the ways of adaptation of the Ruffier-Dickson test for children, a decreased number of squats from 30 to 20 was used [14], in another way it increased in 1 or 2 points or decreased in 1 to 5 points of the original index values [15], and in the third way it increased the index boundaries between the health levels in the original table of assessment for adults in 1.5–6.0 points [16]. These ways do not guarantee validity of the test for primary physical education. To guarantee the Dickson index validity, the results of heart rate measurements should be reduced proportionally to the ratio of the normal heart rate in the young patients' population to the normal heart rate in adults.

The Dickson index values (8.8, 7.9, and 7.6) calculated with the original formula [6] correlate with age (6, 7, and 8 years) and the corresponding population normal hearts rates (102, 98, and 93  $\text{min}^{-1}$ ), which shows the invalidity of the original index used for children. Contrary, there is no correlation between the corrected index values calculated with equation 2 and these parameters show validity of the index corrected for children [11]. This index model could be recommended for use in practice in primary school physical education. This index model is useful not only for small pupils, but for all the pupils of the primary school (6–15

years old), with the consideration of the corresponding normal population heart rate of the age group [8]. The significance of  $t$ -test between the children and adult groups could be accepted as a relative measure of the index validity.

Generally, the problem of the Dickson index validity with regard to testing physical capacity of children appears similar to that of the Ruffier index validity [5]. These issues have the same root: a greater normal heart rate in children than in adults. The way to solve the problems of the Ruffier and Dickson indices regarding primary physical education is the same and consists in correcting the indices values with the reduction of heart rate measures proportionally to the ratio of the normal population heart rate of young patients to the normal population heart rate of adults.

It is easy to notice the practically equal values of Dickson index calculated with the corrected formula (Figure 1, 3 first C columns and the fourth O column) contrary to the values calculated with the original Dickson index formula (Figure 1, all O columns). The invalidity of the original Dickson formula is greater for younger patients (i.e. for 6-year-old pupils); correspondingly, the values of correction are higher. The difference between the adults and separately with each of the 3 children groups was on smaller significance levels:  $p$  values of 0.866, 0.675, and 0.631, respectively, for 6-, 7-, and 8-year-old pupils. The greater significance regarding the united children group could be explained with a smaller difference between its arithmetic mean (3.83) and the adults' arithmetic mean (3.80) in comparison with the arithmetic means of the 3 separate children groups (3.85, 3.67, 3.97).

The  $t$ -test was used to evaluate the validity of the Dickson index adapted for young patients [5] with regard to its original model [6]. The intra-class correlation coefficient was used with the same purpose



as the generalisation of *t*-test on a multiple model. In the modern theory of tests, intra-class correlation is used as a common model of test-retest reliability. In the mathematical theory of test validity, inter-class correlation is applied as the generally acknowledged model [13]. The approach to modelling the test validity was based on the concurrent validity model with the original Dickson index for adults [6] as a well known valid test. The validity of the index corrected for the pupils' age was studied by comparing the corresponding Dickson index values with the original values for adults. This approach showed good validity of the corrected model for young patients.

The corrected Dickson index formula (equation 2) makes it possible to extend the sphere of using the Ruffier-Dickson test on children and adolescents because the correction in the formula increases the validity of the test for this age population up to the validity of the test for adults. The use of the corrected index formula in school physical education allows to evaluate the physical capacity of pupils and to determine the corresponding level of physical efforts in physical education lessons.

Only male subjects were involved in the research to verify the age-corrected formula of the Dickson index. The original formula, as well as the whole Ruffier-Dickson test is intended for males and females without any gender differences. The test has been applied in its original form nearly for the recent 7 decades. Therefore, the Dickson index formula corrected for age verified for the male samples is relevant for females, too. However, verifying the corrected formula among female subjects would not come amiss in future.

## Conclusions

The problem of testing physical capacity in primary school with the use of the Ruffier-Dickson test has been studied, with the verification of the Dickson index corrected for the children age. To guarantee the Dickson index validity, the results of heart rate measurements should be reduced proportionally to the ratio of the normal heart rate of the young patients' population to the normal heart rate in adults. The Dickson index values or the corresponding distribution into the levels of the body readiness to resist physical effort do not depend on the age of healthy participants with normal physical capacity.

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## Disclosure statement

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## Conflict of interest

The authors state no conflict of interest.

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