SECULAR TRENDS IN ANTHROPOMETRIC CHARACTERISTICS AND HEALTH-RELATED PHYSICAL FITNESS IN MACEDONIAN CHILDREN: THE MAKFIT STUDIES

Abdulla Elezi1ABCDE, Gresa Elezi2ABCDE, Seryozha Gontarev3ABCDE, Georgi Georgiev3ABCDE

1University of Pristina
2American Hospital, Pristina
3Ss. Cyril and Methodius University of Skopje

Authors’ Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Corresponding Author: Gresa Elezi, E-mail: gresaelezi@hotmail.com

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Abstract
The purpose of the present study was to analyze the secular trends in anthropometric characteristics and health-related physical fitness (i.e., flexibility, muscular strength and speed/agility) in Macedonian children between 2012 and 2019.

Materials and methods. We analyzed the secular trends in anthropometric characteristics and health-related physical fitness in Macedonian children between 2012 and 2019. Two representative population studies were conducted 7 years apart in children (6-10 years) from Skopje (Macedonia). Both studies used the same anthropometric measures and tests to assess physical fitness: height, weight, body mass index, body fat percentage, muscle mass percentage, sit and reach, handgrip strength, standing long jump, 30 sec sit ups, and 4 × 10 m shuttle run.

Result. The boys and girls measured in 2019 had significantly better performance in the sit and reach (Cohen’s d ~0.4 and ~0.5, respectively), 30 sec sit ups (Cohen’s d ~0.3 and ~0.2, respectively), and 4 × 10 m shuttle run (Cohen’s d ~0.7 and ~0.8, respectively) tests compared to those measured in 2012-2013. Levels of the standing long jump were significantly lower in 2019 in boys and girls (Cohen’s d ~0.6 for both).

Conclusions. Based on the results of the study, it can be concluded that Macedonian children measured in 2019 have higher levels of flexibility, abdominal muscle strength and coordination, speed and agility, but lower levels of explosive force of the lower limbs than their counterparts measured 7 years ago, no statistically significant differences were found in anthropometric measures and measures of body weight.

Keywords: fitness, muscular strength, youth, physical activity.

Introduction
Physical fitness is a powerful marker of childhood health and adolescence (Myers et al., 2002; Andersen et al., 2006). Even in children and adolescents, physical fitness is inversely related to critical physiological factors for occurrence of chronic diseases, including high blood pressure (Sallis et al., 1998; Ruiz et al., 2006), obesity (Ruiz et al., 2006), hyperinsulinemia (Gutin et al., 2004), increased abdominal adiposity (Brunet et al., 2006), atherogenic lipid profile (Mesa et al., 2006) insulin resistance, inflammatory markers (Gulati et al., 2003), and other metabolic risk factors (Brage et al., 2004; Ruiz et al., 2007).

Several meta-analyses have shown a decrease in cardiorespiratory fitness in recent years and a stabilization of muscle strength (Macfarlane & Tomkinson, 2007; Tomkinson & Olds, 2007a; Tomkinson, 2007; Olds et al., 2006; Tomkinson & Olds, 2007b; Tomkinson et al., 2007). Available original reports around the world show different trends depending on the geographic region. To our knowledge, there is no information available regarding the secular trends in physical fitness in Macedonian children. Developing appropriate public health strategies requires regular analysis of the evolution of fitness, especially among young people.

The purpose of the present study was to analyze the secular trends in anthropometric characteristics and health-related physical fitness (i.e., flexibility, muscular strength and speed/agility) in Macedonian children between 2012 and 2019.
Materials and methods

Sample of respondents

In this study we considered data from two separate cross-sectional studies, both representative from the city of Skopje (Macedonia). The research was conducted in seventeen primary schools in the City of Skopje situated in different municipalities. Five classes were randomly selected from each school. Both the first and second measurements were conducted in the same schools. In 2012 the survey was conducted on a sample of 2269 respondents out of which 1110 boys and 1159 girls with an average age of 8.58 ± 1.34 years. In 2019 the survey was conducted on a sample of 2028 respondents of which 1018 boys and 1010 girls with an average age of 8.58 ± 1.33 years.

The study included students for whom their parents had given consent to take part in the research, who were psychically and physically healthy and who regularly attended the classes of physical and health education. Both studies were performed following the ethical guidelines of the Declaration of Helsinki 1961 (revision of Edinburgh 2000). Measurements were realized in March, April and May 2012 and 2019, in standard school conditions at regular classes of physical and health education. The measurement was realized by experts from the area of kinesiology and medicine, previously trained to perform functional tests and to take anthropometric measures.

Anthropometric measures and body composition

Measuring of the anthropometric measurements was realized at the recommendations given by IBP-International Biology Program (Lohman et al., 1988). For estimation of the morphologic characteristics the following anthropometric measures have been applied: body height in standing position (cm), body weight (kg), as well as the body mass index (BMI).

Components of the body composition have been determined by the method of bioelectrical impedance (measuring of the electric conductivity – Bioelectrical Impedance Analysis – BIA). The measuring was realized by a Body Composition Monitor, model “OMRON – BF511”, by means of which we have measured the body weight, fat tissue percent and muscular mass percent. Prior to commencing the measurement, we entered the parameters of gender, years and body height of the respondent in the Body Composition Monitor. In order to provide better precision of the results obtained from the estimation of the body composition, prior to each measuring, we ensured that the preconditions recommended by ACSM (2005) and Heyward (2006) had been fulfilled.

Evaluation of Physical Fitness

Prior to starting the study, the researchers involved in the project undertook training sessions in order to guarantee the standardization, validation, and reliability of the measurements. Five tests, forming part of the EUROFIT battery, validated and standardized by the European Council, were applied in the following order:

Sit and Reach test. With the subject seated on the floor and using a standardized support, the maximum distance reached with the tip of the fingers by forward flexion of the trunk is measured. Test indicative of amplitude of movement or flexibility.

Hand Grip test. With the use of a digital Takei TKK 5101 dynamometer (range, 1-100 kg), the maximum grip strength was measured for both hands.

Standing broad jump test. The maximum horizontal distance attained, with feet together, was measured. This test evaluates lower limb explosive-strength.

Sit-ups 30 sec. Maximum number of sit ups achieved in 30 seconds. This test measures the endurance of the abdominal muscles.

Shuttle run: 4 × 10 meters. This test provides an integral evaluation of the speed of movement, agility and coordination. The subject does four shuttle runs as fast as possible between 2 lines, 10 meters apart. At each end the subject places or picks up an object (a sponge) beside the line on the floor.

Definition of weight status

Three weight status groups were established in this study: underweight/normal weight, overweight and obesity. Participants were categorized according to the international gender and age-specific BMI (kg/m²) cut-off points (Cole et al., 2000, 2007). These points have been particularly established for children and adolescents aged from 2-18 years, separately for males and females and for 0.5 year age groups. These cutoff values are based on percentiles passing at age 18 through BMI 18.5 kg/m² for underweight, 25 kg/m² for overweight and 30 kg/m² for obesity (Cole et al., 2000, 2007).

Statistical analysis

The data are presented as frequencies (percentage) for categorical variables and mean (SD) for continuous variables. Gender differences for each measurement point were assessed by one-way analysis of variance (ANOVA). Categorical data (weight status) were analyzed using the χ² – test. Mean differences of the secular trends in health-related physical fitness performances (i.e., height, weight body mass index, body fat percentage, muscle mass percentage, sit and reach, handgrip strength, standing long jump, 30 sec sit ups and 4 × 10 m shuttle run) between measurement points were analyzed by one-way analysis of covariance (ANCOVA) for boys and girls separately. The measurement point was entered as fixed factor, each fitness test was entered as dependent variable in separate models, and age were entered as covariates. We calculated the effect size statistics as Cohen’s d (standardized mean differences) and 95% confidence interval. Values of Cohen’s d ~0.2, ~0.5 and ~0.8 are considered small, medium and large effects, respectively. All the analyses were performed using the Statistical Package for Social Sciences software (SPSS, v. 22.0 for Windows; SPSS Inc., Chicago, IL, USA), and values of p < 0.05 were considered statistically significant.

Results

The characteristics of the study population by measurement point (2012 and 2019) and gender are shown in Table 1. The table shows that boys in 2012 and 2019 are heavier, have higher body mass index, higher percentage of fat tissue and higher muscle mass, and show better results in all physical assessment tests related to health, except in the deep-seated bend test in which girls show better results.

Table 2 shows the mean of physical fitness tests by gender in both measurement points after controlling for age. The
The results of this study showed that Macedonian children in 2019 have higher levels of flexibility, abdominal muscle strength, coordination, speed and agility, and lower levels of explosive force on the lower limb than their counterparts. The characteristics of the study population by measurement point (2012 and 2019) and gender are shown in Table 1. The performance in physical fitness tests by measurement point and gender is shown in Table 2.

Table 1. The characteristics of the study population by measurement point (2012 and 2019) and gender

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Boys</th>
<th>Girls</th>
<th>P</th>
<th>Boys</th>
<th>Girls</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years 2012</td>
<td>Mean (cm)</td>
<td>SD</td>
<td>Mean (cm)</td>
<td>SD</td>
<td>Mean (cm)</td>
<td>SD</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>134.04</td>
<td>9.92</td>
<td>132.72</td>
<td>9.94</td>
<td>0.002</td>
<td>133.09</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>34.65</td>
<td>10.44</td>
<td>32.72</td>
<td>9.80</td>
<td>0.000</td>
<td>33.98</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>19.00</td>
<td>3.62</td>
<td>18.29</td>
<td>3.49</td>
<td>0.000</td>
<td>19.04</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>24.09</td>
<td>7.56</td>
<td>22.54</td>
<td>8.41</td>
<td>0.000</td>
<td>23.99</td>
</tr>
<tr>
<td>Muscle mass (%)</td>
<td>30.44</td>
<td>3.51</td>
<td>29.82</td>
<td>2.64</td>
<td>0.000</td>
<td>30.32</td>
</tr>
<tr>
<td>Sit and reach (cm)</td>
<td>12.58</td>
<td>5.63</td>
<td>14.49</td>
<td>5.84</td>
<td>0.000</td>
<td>14.74</td>
</tr>
<tr>
<td>Handgrip strength (kg)</td>
<td>14.15</td>
<td>3.91</td>
<td>12.32</td>
<td>3.52</td>
<td>0.000</td>
<td>13.77</td>
</tr>
<tr>
<td>Standing long jump (cm)</td>
<td>122.93</td>
<td>22.98</td>
<td>110.35</td>
<td>19.91</td>
<td>0.000</td>
<td>101.98</td>
</tr>
<tr>
<td>30 sec sit ups (n)</td>
<td>11.95</td>
<td>5.65</td>
<td>10.24</td>
<td>5.79</td>
<td>0.000</td>
<td>13.49</td>
</tr>
<tr>
<td>4 × 10 m shuttle run (s)</td>
<td>16.17</td>
<td>1.80</td>
<td>17.28</td>
<td>1.71</td>
<td>0.000</td>
<td>14.97</td>
</tr>
</tbody>
</table>

Table 2. Performance in physical fitness tests by measurement point and gender

<table>
<thead>
<tr>
<th>Fitness tests</th>
<th>Boys</th>
<th>Girls</th>
<th>p</th>
<th>Cohen's d</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years 2012</td>
<td>n</td>
<td>Mean (cm)</td>
<td>SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standing long jump (cm)</td>
<td>1110</td>
<td>133.59</td>
<td>9.92</td>
<td>1018</td>
<td>0.044</td>
</tr>
<tr>
<td>Handgrip strength (kg)</td>
<td>1108</td>
<td>18.96</td>
<td>3.62</td>
<td>1009</td>
<td>0.363</td>
</tr>
<tr>
<td>30 sec sit ups (n)</td>
<td>1084</td>
<td>30.35</td>
<td>3.51</td>
<td>1009</td>
<td>0.482</td>
</tr>
<tr>
<td>4 × 10 m shuttle run (s)</td>
<td>1112</td>
<td>11.81</td>
<td>5.66</td>
<td>1021</td>
<td>0.560</td>
</tr>
</tbody>
</table>

Boys

| Height (cm)                         | 1110         | 133.59       | 9.92 | 1018       | 0.044        | 0.944        | 0.00   | -0.585 to 0.604 |

Girls

| Height (cm)                         | 1110         | 133.59       | 9.92 | 1018       | 0.044        | 0.944        | 0.00   | -0.585 to 0.604 |

Values are adjusted means ± standard deviation. p values from one-way analysis of covariance after controlling for age. In this test, lower scores (time in s) indicate better performance.

Table 3, 4 shows the change in the percentage of boys and girls in this study who were classified as normal, overweight and obese between 2012 and 2019. The analysis of table 3 and the overview of χ² test indicate that there are no statistically significant differences in boys and girls in nutrition levels between 2012 and 2019.

Discussion

The results of this study showed that Macedonian children in 2019 have higher levels of flexibility, abdominal muscle strength, coordination, speed and agility, and lower levels of explosive force on the lower limb than their counterparts.
Table 3. The proportion of boys classified as normal, overweight or obese using the Cole et al cut-offs

<table>
<thead>
<tr>
<th>BMI classification</th>
<th>Years 2012</th>
<th>Years 2019</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Normal weight*</td>
<td>627</td>
<td>56.60%</td>
</tr>
<tr>
<td>Overweight</td>
<td>281</td>
<td>25.40%</td>
</tr>
<tr>
<td>Obese</td>
<td>200</td>
<td>18.10%</td>
</tr>
</tbody>
</table>

*Difference between measurement point (Chi-Square Tests); ns, non-significant.

Table 4. The proportion of girls classified as normal, overweight or obese using the Cole et al cut-offs

<table>
<thead>
<tr>
<th>BMI classification</th>
<th>Years 2012</th>
<th>Years 2019</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Normal weight*</td>
<td>701</td>
<td>60.70%</td>
</tr>
<tr>
<td>Overweight</td>
<td>272</td>
<td>23.60%</td>
</tr>
<tr>
<td>Obese</td>
<td>181</td>
<td>15.70%</td>
</tr>
</tbody>
</table>

*Difference between measurement point (Chi-Square Tests); ns, non-significant.

7 years ago. The percentage of overweight and obese children classified on the basis of the BMI criterion in 2012 was 41%, while in 2019 it was 40%. Similar results for overweight and obesity have been obtained in several international studies (Jehn et al., 2006; Ortega et al., 2007; Al-Nakeeb et al., 2007; Ostojic et al., 2011). Over 20% of the respondents in both 2012 and 2019 have a body fat percentage greater than 30%. Such a high percentage of body fat is associated with an increased risk of acute and chronic diseases especially osteoarthritis, hypertension, diabetes mellitus and cardiovascular disease, which can lead to poorer quality of life and increased financial burden of the individual, the family and the society, as well as shorten life expectancy (Williams et al., 1992; Dugan, 2008).

Several meta-analyses describe global changes in components of physical fitness related to health (Tomkinson & Olds, 2007; Tomkinson, 2007). Studies covering 27 countries and five geographic regions have shown a decrease in cardio-respiratory fitness from late 1970 to 2003, (Tomkinson & Olds, 2007) whereas performance at power and speed tests remained fairly stable from 1980s. (Tomkinson, 2007). Other meta-analyses performed on large samples yielded similar results (Macfarlane & Tomkinson, 2007), but they were mainly focused on exploring cardio-respiratory fitness (Olds et al., 2006; Tomkinson & Olds, 2007; Tomkinson et al., 2007). Macfarlane and Tomkinson (2007) analyzed the secular changes in strength, speed and cardiovascular fitness tests in 23.5 million Asian children aged 6 to 19 years between 1917 and 2003 and found a steady decline in cardio-respiratory fitness over the last 10-15 years, and a global stabilization in power and speed. Tomkinson and Olds (2007) analyzed 46 studies and identified changes in cardio-respiratory fitness in 161,419 Australian children aged 6 to 17 years from 1961 to 2002 and found a marked decline in the youngest children and boys until about 1990 that appears to be slowing. Tomkinson et al. (2007) analyzed aerobic performance data of over 22 million Koreans (6-18 years) between 1968 and 2000 and found a significant decrease in the years after 1984.

The rich history of pediatric fitness testing all around the world shows many original reports about secular trends in adolescent health-related physical fitness in peer-reviewed scientific journals, especially focused on cardiorespiratory fitness. Analyzes of other health-related components such as muscle strength, speed, or agility show uneven trends across geographic regions (Matton et al., 2007; Albon et al., 2010; Jurimae, et al., 2007; Tomkinson et al., 2003). Matton et al. (2007) conducted a representative sample of Flemish adolescents aged 12 to 18 between 1969 and 2005 and found a decrease in bent arm hang and 10 × 5 m shuttle run results in girls, and an improvement in the results of the boys in 10 × 5 m shuttle run. Albon et al. (2010) analyzed changes in New Zealand children between 1991 and 2003 and did not find significant differences in the 4 × 9 m shuttle run and the standing long jump tests. Jurimäe et al. (2007) analyzed secular trends of Estonian and Lithuanian children and adolescents in 1992 and 2002. Lithuanian’s respondents reported a decrease in test scores bent arm hang, standing long jump and 20 m shuttle run, whereas in the Estonian respondents only a decrease in the results of the bent arm hang tests was found. Test results in 10 × 5m shuttle run in Lithuanians and standing long jump, 10 × 5 m and 20 m shuttle run tests in Estonians remained unchanged. Tomkinson et al. (2003) investigated the fitness trends of 18,631 South Australian students (12-15 years) between 1995 and 2000 and found a statistically significant decrease in the 20 m shuttle run and 40 m sprint test results, but found no statistically significant changes in the vertical jump tests. Moliner-Urdiales et al. (2010) researched the secular trends in health-related physical fitness in Spanish adolescents between 2001-2002 and 2006-2007. Both studies used the same tests to assess physical fitness: the handgrip strength, bent arm hang, standing broad jump, 4 × 10 m shuttle run and 20 m shuttle run tests. The results indicate that levels of both speed/agility and cardiorespiratory fitness were higher in 2006-2007 than in 2001-2002, whereas muscular strength components were lower in 2006-2007.

Although there is consistency in the secular trends identified in other studies conducted on the population of children and adolescents, our results do not fully coincide with the above studies. The increase in flexibility, strength of abdominal muscles, coordination, speed and agility while the decrease in lower body musculature, discard theories related to the increases of fat mass over the reported changes in physical fitness components. And the results of this study disprove this theory, namely that anthropometric measures and body composition measures (fat percentage and muscle mass) did not detect statistically significant differences between the two sexes in 2012 and 2019. According to the model established by Tomkinson (Tomkinson & Olds, 2007; Tomkinson, 2007) we agree in that the reported secular trends in physical fitness are caused by a network of social, behavioral, physical, psychosocial and physiological factors.

Despite the lack of information on secular trends in other populations in recent years, which confirms our findings, the results obtained in this study can be attributed to various factors. The popularity of the more holistic approach to physical activity and exercise over the last decade has seen an increase in activities that have an emphasis on core strength, stability and flexibility (Chang, 2000). These exercises find their way into the physical education curriculum (Kloubec & Banks, 2004) and may affect children in this study. Other factors such as a change in the ergonomics of the schools’ seats cannot be discounted, and further research is required to uncover the causes of this positive trend.
The major strength of the present study is the use of identical protocols, sampling methods and sampling frames in two representative cohorts of children from Skopje (Macedonia), as well as the application of valid, reliable and objective fitness tests to assess health-related fitness, and the recent measurement data (2019). It is important to consider when interpreting the findings from the present study that only two dataset including children from Skopje (Macedonia), were used over a 7 years period.

Conclusions

Based on the results of the study it can be concluded that the Macedonian children measured in 2012-2019 have higher levels of flexibility, abdominal muscle strength and coordination, speed and agility, and lower levels of explosive force on the lower limb than their counterparts measured 7 years ago. In order to guarantee healthy levels of physical fitness, Macedonian public health programs should promote physical activity among children, especially focussed on muscular strength which was seen to decrease and measures for decrease in obeasety among this group of the population. Schools may play a key role, and parents also have a great responsibility to encourage and support active living of their off spring.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article

References


Anthropometric standardization reference manual. 


ВІКОВІ ТЕНДЕНЦІЇ В АНТРОПОМЕТРИЧНИХ ХАРАКТЕРИСТИКАХ ТА ФІЗІЧНІЙ ПІДГОТОВЛЕНОСТІ У МАКЕДОНСЬКИХ ДІТЕЙ: ДОСЛІДЖЕННЯ МАКФІТА

Абдулла Елезі1АВСDE, Іресь Елеzi2АВСDE, Сержьога Гонтарев3АВСDE, Георгій Георгієв3АВСDE

1Університет в Приштині
2Американська лікарня, Приштина
3Кирило-Мефодіївський університет в Скоп’є

Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 7 с., 4 табл., 34 джерела.

Мета дослідження – проаналізувати вікові тенденції в антропометричних характеристиках та фізичній підготовленості у македонських дітей між 2012 та 2019 роками.

Матеріали та методи. Проаналізовані вікові тенденції в антропометричних характеристиках та фізичній підготовленості, пов’язані з здоров’ям, у македонських дітей між 2012 та 2019 рр. Проведено два репрезентативні дослідження популяції з різницею у 7 років у дітей (6-10 років) із Скоп’є (Македонія). В обох дослідженнях використовували однакові антропометричні вимірювання та тести для оцінки фізичної підготовленості: зріст, маса тіла, індекс маси тіла, відсоток жиру в тілі, відсоток м’язової маси, нахил тулуба з положення сидячи, сила кисті, стрибки у довжину з місця, 30-секундні присідання та човниковий біг 4 × 10 м.

Результати. Хлопчики та дівчатка, дані 2019 року, мали значно кращі показники в тестах нахил тулуба з положення сидячи (d ~0.4 і ~0.5 Коена відповідно), 30-секундні присідання (d ~0.3 і ~0.2 Коена відповідно) і човниковий біг 4 × 10 м (тести Коена d ~0.7 та ~0.8 відповідно) порівняно з результатами тестування 2012-2013 рр. У стрибках у довжину зі значеннями результатами були значно нижчими у 2019 році у хлопчиків та дівчаток (d Коена ~0.6 для обох груп).

Висновки. Македонські діти у 2019 році, мають вищий рівень гнучкості, сили та координації, швидкості та спритності, але нижчий рівень вибухової сили нижніх кінцівок, ніж їхні однолітки 7 років потому. Статистично значущих відмінностей в антропометричних вимірах та показниках маси тіла не виявлено.

Ключові слова: фітнес, м’язова сила, діти, фізична активність.

Information about the authors:

Elezi A.: abdulla.elezi@uni-pr.edu; https://orcid.org/0000-0003-0225-7494; Faculty of Physical Education and Sport, University of Pristina, Kosovo; Industrial Zone, Pristina, 10000, Kosovo.

Elezi G.: gresaelezi@hotmail.com; https://orcid.org/0000-0002-1937-4294; American Hospital, Industrial Zone, Pristina, 10000, Kosovo.

Gontarev S.: gontarevserjozal@gmail.com; https://orcid.org/0000-0001-5873-2974; Faculty of Physical Education, Sport, and Health, Ss. Cyril and Methodius University of Skopje, Dimitre Mircev, 3, Skopje, 1000, Republic of North Macedonia.

Georgiev G.: georgiegeorgiev63@yahoo.com; https://orcid.org/0000-0002-1748-9477; Faculty of Physical Education, Sport and Health, Ss. Cyril and Methodius University of Skopje, Dimitre Mircev, 3, Skopje, 1000, Republic of North Macedonia.


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