Original Contribution

Birth Size and Childhood Growth as Determinants of Physical Functioning in Older Age

The Helsinki Birth Cohort Study


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The study reports on the associations of infant and childhood anthropometric measurements, early growth, and the combined effect of birth weight and childhood body mass index with older age physical functioning among 1,999 individuals born in 1934–1944 and belonging to the Helsinki Birth Cohort Study. Physical functioning was assessed by the Short Form 36 scale. Anthropometric data from infancy and childhood were retrieved from medical records. The risk of lower Short Form 36 physical functioning at the mean age of 61.6 years was increased for those with birth weight less than 2.5 kg compared with those weighing 3.0–3.5 kg at birth (odds ratio (OR) = 2.73, 95% confidence interval (CI): 1.57, 4.72). The gain in weight from birth to age 2 years was associated with decreased risk of lower physical functioning for a 1-standard deviation increase (OR = 0.84, 95% CI: 0.75, 0.94). The risk of lower physical functioning was highest for individuals with birth weight in the lowest third and body mass index at 11 years of age in the highest third compared with those whose birth weight was in the middle third and body mass index at age 11 years was in the highest third (OR = 3.08, 95% CI: 1.83, 5.19). The increasing prevalence of obesity at all ages and the aging of populations warrant closer investigation of the role of weight trajectories in old age functional decline.

Population aging has led to larger numbers of people surviving to very old age. Maintaining adequate physical functioning in older age is crucial for leading an independent life, performing daily tasks, and decreasing the need for health and social care (1, 2). Life-course epidemiology posits that physical or social exposures taking place during gestation, childhood, adulthood, and older age have long-term effects on old age health and functioning (3). Small body size at birth and slow growth during infancy predict chronic diseases such as hypertension, cardiovascular disease, and diabetes in late adulthood (4–6). These chronic conditions are known risk factors for decreased physical functioning, which in turn strongly predicts subsequent disability at the distal end of the lifespan (1, 7). Some evidence exists on the association between lower birth weight and suboptimal infant growth and decreased muscle strength and physical performance in later life (8–13)—the intermediate outcomes in the development of old age disability and premature mortality (14–17). However, little is still known about the relation between early growth and physical functioning in older age.

The association among low birth weight, slow infant growth followed by rapid weight gain after the age of 2 years, also referred to as “catch-up growth,” and increased prevalence of chronic diseases in adulthood has been documented (18–23), but we did not find any reports of the association between this path of growth and physical functioning in old age. Here, we report on the associations of infant and childhood anthropometric measurements, early growth, and the combined effect...
of birth weight and childhood body mass index with physical functioning assessed at the mean age of 61.6 years in 1,999 individuals belonging to the Helsinki Birth Cohort Study.

**MATERIALS AND METHODS**

**Study population**

The Helsinki Birth Cohort Study includes 8,760 individuals born at the Helsinki University Central Hospital between 1934 and 1944 and living in Finland in 1971 when a unique personal identification number was assigned to all Finnish residents (4, 24). All 7,079 (80.8%) living members of this epidemiologic cohort who resided in Finland in the year 2000 were sent a questionnaire, and a total of 4,515 (63.8%) responded. Of these, a random sample of 2,901 were invited to participate in clinical examinations. Of these, 2,003 (69.1%) participated at an average age of 61 years in the examinations conducted between the years 2001 and 2004. The longitudinal data used in the present study include 1,999 participants (927 men and 1,072 women) with data on physical functioning assessed with a questionnaire at the time of clinical examination. Compared with the 8,760 members of the original cohort, the individuals who participated in the clinical examination had 30 g higher birth weight (95% confidence interval (CI): 6, 54; \( P = 0.02 \)) and 0.08 kg/m\(^2\) higher body mass index at birth (95% CI: 0.02, 0.14; \( P = 0.02 \)), but their length at birth and length of gestation were similar (25).

**Ethics statement**

The study complies with the guidelines of the Declaration of Helsinki. The study was approved by the Ethics Committee of Epidemiology and Public Health of the Hospital District of Helsinki and Uusimaa and that of the National Public Health Institute, Helsinki. All participants gave a written, informed consent.

**Infant and childhood measures**

Dates of birth and the mother’s last menstrual period prior to the pregnancy with the participant, as well as the weight and length at birth, were retrieved from hospital birth records. Infancy and childhood weight and height were retrieved from child welfare clinic and school health records. These have been described in detail previously (18, 19, 26). Body mass index was calculated (weight (kg)/height (m)\(^2\)). The duration of breastfeeding was categorized as not breastfed and breastfed for less than 3 months, 3–6 months, and more than 6 months. Childhood socioeconomic status was evaluated on the basis of the father’s occupation indicated by the highest occupational class extracted from the birth and child welfare and school health records. The socioeconomic status was classified into 4 categories (upper middle class, lower middle class, laborers, and unknown occupation) according to the social classification system issued by Statistics of Finland (27).

**Adult data collection**

The participants were measured for weight and height at the clinical examination at a mean age of 61.6 years. Lean body mass was assessed with bioelectrical impedance by using the InBody 3.0 eight-polar tactile electrode system (Biospace Co., Ltd., Seoul, Korea) (28). Participants’ smoking status was assessed with questionnaires at the clinical examination (never smoked, former smoker, smokes currently). Register data from the Finnish Population Register Centre were used to indicate adult socioeconomic status. The highest occupational class at 5-year intervals between 1970 and 1995 was categorized into upper middle class, lower middle class, self-employed, and laborers (27).

**Short Form 36 physical functioning**

At the clinical examination, general health-related physical functioning was assessed with the Finnish validated version of the RAND 36-Item Health Survey 1.0 (Short Form 36 (SF-36)) physical functioning scale (29–32). It has been widely used in assessing physical functioning in the older population (33, 34). The SF-36 has been found to be a reliable and valid measure of health-related quality of life in the Finnish population (31). The 10 items included in the SF-36 physical functioning score (herein referred to as “SF-36 physical functioning”) included vigorous activities; moderate activities; lifting or carrying groceries; climbing several flights of stairs; climbing 1 flight of stairs; bending, kneeling, or stooping; walking more than 1 mile (1.6 km); walking several blocks; walking 1 block; and bathing and dressing oneself. The 10 items were coded into 0 = a lot of problems or unable to perform, 50 = some problems, and 100 = no problems, and they were then summarized and divided by 10 (29). The scores ranged between 0 and 100, with a median score of 90 for men and 85 for women. Participants with SF-36 physical functioning scores in the lowest gender-specific third of the distribution were classified as having lower physical functioning (cutoff score: 85 for men and 75 for women).

**Statistical analyses**

Pearson’s chi-square test was used for comparing proportions for categorical variables, and Student’s \( t \) test was used for comparing means for continuous variables. Individuals who scored in the lowest third were compared with those who scored in the 2 highest thirds of the SF-36 physical functioning. All significance tests were performed as 2 tailed with the significance level set at 0.05. The analyses were first conducted separately for men and women but are presented together, while the results were similar for both genders (\( P_{interaction} > 0.073 \)).

The association between weight measured at birth, 12 months, and 24 months, categorized into 5 groups (4, 18, 35), and SF-36 physical functioning at age 61.6 years was investigated with multiple logistic regressions. The analyses were first adjusted for gender, chronologic age at the time of the clinical examination, and length of gestation; next, we added into the models lean body mass to control for adult body size; and finally, the models were adjusted for childhood and adulthood socioeconomic status and smoking status.

To further explore these associations, we converted weight, height, and body mass index measurements at birth and at 2, 7, and 11 years of age into \( z \) scores (19, 26). The \( z \) score...
represents the difference from the mean value for the whole cohort and is expressed in standard deviations. Linear regression models were performed to confirm the results by using SF-36 physical functioning as a continuous 7-category outcome. The relation between birth weight and SF-36 physical functioning at age 61.6 years was U-shaped, which is why a quadratic term was added to the linear regression models. Conditional growth was explored with logistic regression models for weight, height, and body mass index in 3 periods that have been used in previous analyses of these data (ages 0–1.9, 2–6.9, and 7–11 years) (35) by using standardized residuals from linear regression models. In this procedure, body size at each time point was regressed on corresponding measures at earlier time points, creating completely uncorrelated residuals reflecting conditional growth (19, 36). Logistic regression models were performed to investigate the combined effect of birth weight and body mass index at 11 years of age on physical functioning at age 61.6 years. Birth weight and body mass index were divided into distribution-based thirds (19, 20). All these analyses were adjusted first for gender, chronologic age, and length of gestation and second for childhood and adulthood socioeconomic status, lean body mass, and smoking status. The growth analyses were additionally adjusted for duration for breastfeeding. The analyses were carried out with SPSS, version 18, software (SPSS, Inc., Chicago, Illinois).

RESULTS

Cohort characteristics

The mean age of the 1,999 participants was 61.6 years (range: 56.7–69.8 years). The level of limitation in SF-36 physical functioning is presented in Table 1. The least limitations were perceived in walking 1 block (limited at least a little: men, 4%; women, 6%), and most limitations were reported in vigorous activities, such as running and lifting heavy objects (limited at least a little: men, 70%; women, 80%).

The characteristics of those in the lowest third compared with those in the 2 highest thirds of the SF-36 physical functioning are described in Table 2. Those with lower SF-36 physical functioning were older and heavier and had a higher lean body mass at age 61.6 years than those in the 2 highest thirds of physical functioning (Student’s t test, P < 0.029). The individuals in the lowest third of SF-36 physical functioning had lower educational attainment (Student’s t test, P ≤ 0.001) and belonged more frequently to a lower social class in childhood and adulthood (Pearson’s chi-squared test, P < 0.001).

Body size at birth and infancy

Table 3 shows the odds ratios for lower SF-36 physical functioning at age 61.6 years according to birth and infant weight. Low birth weight increased the risk of lower physical functioning. The highest odds were seen for those with birth weight less than 2.5 kg (fully adjusted odds ratio (OR) = 2.73, 95% CI: 1.57, 4.72) and 2.5–3.0 kg (OR = 1.50, 95% CI: 1.10, 2.04) compared with those weighing 3.1–3.5 kg at birth. The finding was further confirmed in a linear regression (quadratic term β = −0.071, 95% CI: −0.128, −0.014; P = 0.015). The association between infant weight and SF-36 physical functioning was parallel. Weighing less than 9.0 kg at 1 year of age increased the odds of SF-36 physical functioning at age 61.6 years compared with those weighing 12.0 kg or more after adjustment for adult lean body mass (OR = 2.02, 95% CI: 1.09, 3.73) (linear regression β = 0.120, 95% CI: 0.023, 0.216; P = 0.015). Lower weight at 2 years of age increased the risk for lower SF-36 physical functioning at age 61.6 years (linear regression β = 0.192, 95% CI: 0.092, 0.292; P < 0.001). For example, the odds for lower physical functioning were 3.58 (95% CI: 1.97, 6.51) times higher for


Table 1. Physical Functioning (Percent and Mean Score) at a Mean Age of 61.6 Years Among 927 Men and 1,072 Women Born in 1934–1944 and Belonging to the Helsinki Birth Cohort Study

<table>
<thead>
<tr>
<th>SF-36 Physical Functioning Scale</th>
<th>Men (n = 927)</th>
<th>Women (n = 1,072)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not Limited, %</td>
<td>Limited a Little, %</td>
</tr>
<tr>
<td>Vigorous activities (running, lifting heavy objects)</td>
<td>30.5</td>
<td>43.3</td>
</tr>
<tr>
<td>Moderate activities (moving a table, vacuuming, bowling)</td>
<td>80.2</td>
<td>16.8</td>
</tr>
<tr>
<td>Lifting or carrying groceries</td>
<td>87.4</td>
<td>10.2</td>
</tr>
<tr>
<td>Climbing several flights of stairs</td>
<td>64.3</td>
<td>28.4</td>
</tr>
<tr>
<td>Climbing 1 flight of stairs</td>
<td>90.5</td>
<td>7.4</td>
</tr>
<tr>
<td>Bending, kneeling, or stooping</td>
<td>59.2</td>
<td>32.8</td>
</tr>
<tr>
<td>Walking more than 1 mile&lt;sup&gt;a&lt;/sup&gt;</td>
<td>79.3</td>
<td>15.0</td>
</tr>
<tr>
<td>Walking several blocks</td>
<td>90.6</td>
<td>6.8</td>
</tr>
<tr>
<td>Walking 1 block</td>
<td>95.6</td>
<td>3.3</td>
</tr>
<tr>
<td>Bathing or dressing oneself</td>
<td>93.1</td>
<td>5.7</td>
</tr>
</tbody>
</table>

Abbreviations: SD, standard deviation; SF-36, Short Form 36.
<sup>a</sup> One mile = 1.6 km.
those who had weighed less than 11.0 kg at 2 years of age compared with those who had weighed 14.0 kg or more. All these odds were little changed by further adjustment for adulthood physical activity behavior, alcohol consumption, and chronic physician-diagnosed diseases including hypertension, heart congestion, angina, diabetes, stroke, depression, and asthma. Furthermore, the interaction between birth weight and highest social status in childhood was not significant ($P_{interaction} = 0.73$).

**Infant and childhood growth**

Conditional growth was calculated for the age periods of 0–1.9 years, 2–6.9 years, and 7–11 years (Table 4). The analyses indicate the difference between body size measured at a specific age and body size at that age as predicted by earlier measurements. After adjustment for gender, chronologic age and length of gestation, duration of breastfeeding, childhood and adulthood socioeconomic status, lean body mass, and smoking status, the gain in weight ($OR = 0.84$, 95% CI: 0.75, 0.94) and body mass index ($OR = 0.88$, 95% CI: 0.79, 0.98) from birth to 1.9 years of age were associated with a decreased risk of lower SF-36 physical functioning at 61.6 years of age. The gains in weight and body mass index from 7 to 11 years were associated with an increased risk of lower physical functioning; however, adjustment for adult lean body mass attenuated the association.

**Birth weight and childhood body mass index**

The body mass index at 11 years of age did not correlate with physical functioning at 61.6 years of age ($P_{trend} = 0.091$).
but the interaction between birth weight and body mass index at 11 years of age was statistically significant \( (P_{\text{interaction}} = 0.013) \). Thus, we investigated the combined effect of birth weight and body mass index at 11 years of age, both divided into thirds, on physical functioning at age 61.6 years, presented in Table 5. In the simultaneous regression, the highest odds for lower physical functioning were found among individuals with birth weight in the lowest third and body mass index at 11 years of age in the highest third compared with the individual with birth weight in the mid-third and body mass index at 11 years of age in the highest third (referent) (OR \( = 2.93, 95\% \text{ CI: } 1.80, 4.79 \)). Adjusting the models for adult lean body mass, highest socioeconomic status in childhood and adulthood, and smoking status increased the odds ratio to \( 3.08 (95\% \text{ CI: } 1.83, 5.19) \) compared with the referent. The odds ratio for lower SF-36 physical functioning was also increased for the individuals with birth weight and body mass index at 11 years of age in the highest third compared with the referent (OR \( = 1.58, 95\% \text{ CI: } 1.05, 2.38 \)). The results were similar when birth weight and body mass index at 7 years were regressed simultaneously on physical functioning at age 61.6 years. However, there was no interaction between birth weight and body mass index at 7 years of age.

**DISCUSSION**

We have shown in this well-characterized birth cohort that lower weight at birth and infancy predicted lower general health-related physical functioning at age 61.6 years. The individuals with lower physical functioning in older age had gained weight slower during infancy. Individuals with low
The association between early size and growth and later life physical performance has been reported so far in 2 studies that used objectively measured performance tests as outcomes. In the British 1946 birth cohort, weight gain until 7 years of age was beneficial for performance at age 53 years among men (8). In the Hertfordshire cohort, lower birth weight correlated with lower physical performance among men with an average age of 68 years, but early size and conditional growth in infancy did not correlate consistently with physical performance (11). Our current findings on health-related physical functioning are in line with these earlier findings, but they add new knowledge in terms of analyses of serial measures on weight and height available in our data throughout infancy, enabling us to investigate these effects at several time points during early life.

This is the first study to report on the association between a combination of lower birth weight and higher childhood body mass index and physical functioning in older age. We cannot compare these findings with those of other studies but conclude that they parallel earlier findings on increased incidence of hypertension and coronary heart disease found in this cohort for those with low birth weight and high childhood body mass index (18–21, 26, 35, 38).

The mechanisms and pathways through which birth parameters and early growth are linked to physical functioning in older age are likely to be diverse. One of the underlying reasons might be the suboptimal prenatal environment, reflected in small body size at birth, which may permanently retard developing vital organ structures and functioning of biologic mechanisms and cause unfavorable changes in body composition (39, 40). It has been postulated that prenatal development of organs and tissue is hierarchical in nature and that restricted prenatal nutrition might result in an unfavorable trade-off of muscle tissue by the fetus in securing necessary supply to vital organs such as the brain (40). Babies who are born lighter lack muscle (41), supporting this trade-off. Lower birth weight correlates further with lower adult lean body mass (13, 42, 43) and muscle strength in later life (9, 10, 12, 13). Furthermore, rapid weight gain during childhood might result in an imbalance between fat and muscle mass, as there is little replication in muscle tissue after infancy (44, 45). Second, lower birth weight increases the incidence of chronic diseases such as diabetes, coronary heart disease.

### Table 4. Odds for Lower SF-36 Physical Functioning at Age 61.6 Years for a 1-SD Increase in Conditional Growth From Birth to 11 Years of Age Among Participants Born in 1934–1944 and Belonging to the Helsinki Birth Cohort Study

<table>
<thead>
<tr>
<th>Birth Weight (kg)</th>
<th>Model 1&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Model 2&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR 95% CI</td>
<td>OR 95% CI</td>
</tr>
<tr>
<td>0–1.9 years</td>
<td>0.89 0.80, 0.98</td>
<td>0.84 0.75, 0.94</td>
</tr>
<tr>
<td>2–6.9 years</td>
<td>1.06 0.95, 1.18</td>
<td>0.99 0.88, 1.12</td>
</tr>
<tr>
<td>7–11 years</td>
<td>1.11 1.01, 1.23</td>
<td>1.07 0.96, 1.19</td>
</tr>
<tr>
<td>Height (m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–1.9 years</td>
<td>0.97 0.88, 1.08</td>
<td>0.91 0.81, 1.02</td>
</tr>
<tr>
<td>2–6.9 years</td>
<td>0.98 0.88, 1.09</td>
<td>0.93 0.83, 1.05</td>
</tr>
<tr>
<td>7–11 years</td>
<td>0.99 0.89, 1.09</td>
<td>0.97 0.87, 1.09</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–1.9 years</td>
<td>0.89 0.80, 0.98</td>
<td>0.88 0.79, 0.98</td>
</tr>
<tr>
<td>2–6.9 years</td>
<td>1.08 0.97, 1.20</td>
<td>1.05 0.94, 1.17</td>
</tr>
<tr>
<td>7–11 years</td>
<td>1.13 1.02, 1.25</td>
<td>1.07 0.96, 1.19</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; CI, confidence interval; OR, odds ratio; SD, standard deviation; SF-36, Short Form 36.

<sup>a</sup> The top and middle thirds vs. the lowest third of the SF-36 score (cutoff at 85 for men and 75 for women).

<sup>b</sup> Adjusted for gender, chronologic age, and length of gestation.

<sup>c</sup> Adjusted for gender, chronologic age, length of gestation, adult lean body mass index, highest social class in childhood and adulthood, and smoking status.

Birth weight (<3.0 kg) and later at 11 years of age either high (>17.5) or low (<16.0) body mass index were at an especially high risk for poor physical functioning in older age. These associations were independent of childhood socioeconomic status and adulthood lean body mass, socioeconomic status, and smoking status. These findings indicate that prenatal and childhood growth set the mark for old age physical functioning.

### Table 5. Odds Ratios for Lower SF-36 Physical Functioning at Age 61.6 Years According to Birth Weight and Body Mass Index at 11 Years of Age Among Participants Born in 1934–1944 and Belonging to the Helsinki Birth Cohort Study

<table>
<thead>
<tr>
<th>Birth Weight (kg)</th>
<th>Body Mass Index (kg/m²) at 11 Years of Age</th>
<th>16–17.5</th>
<th>&gt;17.5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR&lt;sup&gt;b&lt;/sup&gt; 95% CI OR&lt;sup&gt;c&lt;/sup&gt; 95% CI</td>
<td>OR&lt;sup&gt;b&lt;/sup&gt; 95% CI OR&lt;sup&gt;c&lt;/sup&gt; 95% CI</td>
<td>OR&lt;sup&gt;b&lt;/sup&gt; 95% CI OR&lt;sup&gt;c&lt;/sup&gt; 95% CI</td>
</tr>
<tr>
<td>&lt;3.0</td>
<td>1.93 1.21, 3.06 2.46 1.51, 4.03</td>
<td>1.46 0.85, 2.51 1.57 0.88, 2.80</td>
<td>2.93 1.80, 4.79 3.08 1.83, 5.19</td>
</tr>
<tr>
<td>3.0–3.5</td>
<td>1.67 1.12, 2.50 1.92 1.25, 2.95</td>
<td>1.22 0.81, 1.84 1.25 0.80, 1.93</td>
<td>1.00</td>
</tr>
<tr>
<td>&gt;3.5</td>
<td>1.56 1.00, 2.43 1.58 0.98, 2.55</td>
<td>1.29 0.87, 1.93 1.37 0.90, 2.09</td>
<td>1.74 1.19, 2.56 1.58 1.05, 2.38</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; OR, odds ratio; SF-36, Short Form 36.

<sup>a</sup> The top and middle thirds vs. the lowest third of the SF-36 score (cutoff at 85 for men and 75 for women).

<sup>b</sup> Adjusted for gender, chronologic age, and length of gestation.

<sup>c</sup> Adjusted for gender, chronologic age, length of gestation, adult lean body mass, highest social class in childhood and adulthood, and smoking status.
and stroke (5, 20, 26), which further increase the prevalence of old age disability (46, 47).

Suboptimal early body size and growth might render the individual more susceptible to the negative effects of an unfavorable social environment (21), which has been linked with poor physical function in later life (48). However, the interactions between childhood socioeconomic status and weight and growth in infancy and childhood were not statistically significant, indicating that these effects were independent of childhood socioeconomic status.

Strengths and limitations

The strengths of our study include the well-characterized sample and serial measures of body size during infancy and childhood collected from reliable medical records. We were also able to use register-based data on socioeconomic status in adulthood. Some limitations of the study should be recognized. The individuals in this study had been born in Helsinki University Central Hospital, and the majority went to school in Helsinki. They had all attended voluntary child-welfare clinics that were free of charge. Thus, the participants may not represent the entire population living in Finland. However, at birth, childhood social class as indicated by the father’s highest occupational status did not differ from that of the population living in the city of Helsinki at that time (4). In this historical cohort, most individuals were born or grew up during the Second World War, a time during which families might have suffered from food shortages in Finland. This must be considered when generalizing these results to current settings. Furthermore, survivor bias might cause some underestimation in terms of the results while the participants had to live to be about 60 years of age and to be able to participate in the clinical examinations. Small size at birth predicts premature death and several chronic diseases (4, 5, 49), causing individuals to drop out from the follow-ups of studies more frequently. The data on physical functioning were self-reported, which might yield possible reporting bias; however, high correlations between subjective and objectively measured physical performance have been reported (50). The SF-36 physical functioning scores in this study corresponded to the scores reported for men and women aged 59–72 years who belonged to the Hertfordshire Cohort Study (50).

Conclusion

In conclusion, we found that lower physical functioning at age 61.6 years was associated with lower weight, as well as slower weight gain, during infancy. Furthermore, low birth weight combined with either high or low body mass index in childhood yielded the highest risks for lower physical functioning in older age. This piece of information is important as the numbers of obese individuals in all age groups increase and body mass index tends to track through adolescence into adulthood and further increase the risk for old age disability (51–53). These results offer new insights in terms of the effects of pre- and postnatal environment on older age physical functioning and are in line with other findings on the relation between early life parameters and health-related outcomes in adulthood.

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