

# **The epidemiology of muscle-strengthening and aerobic physical activity guideline adherence among 24,016 German adults**

Jason A Bennie<sup>\*</sup>, Katrien De Cocker<sup>1</sup> and Susanne Tittlbach<sup>2</sup>

1. Physically Active Lifestyles Research Group (USQ PALs), Centre for Health Research, Institute for Resilient Regions, University of Southern Queensland, Queensland, Australia.

2. Social and Health Sciences in Sport, Institute of Sport Science, University of Bayreuth, Bavaria, Germany.

## **\*Corresponding author**

Dr Jason Bennie

Physically Active Lifestyles Research Group (USQ PALs),

Centre for Health Research, Institute for Resilient Regions, University of Southern

Queensland

Education City, 37 Sinnathamby Boulevard, Springfield Central, Queensland, 4300, Australia

E: [jason.bennie@usq.edu.au](mailto:jason.bennie@usq.edu.au)

P: +61 (0) 430 283 352 (mobile)

P: +61 (7) 3470 4136 (office)

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## Abstract

Despite the 2016 German ‘*National Recommendations for Physical Activity and Physical Activity Promotion*’ stating that adults ( $\geq 18$  years) should engage in: [i]  $\geq 150$  minutes of aerobic moderate-to-vigorous-intensity physical activity/week (MVPA); and [ii]  $\geq 2$  days/week of muscle-strengthening exercise (MSE), there is limited research on the descriptive epidemiology on the adherence to these guidelines among German adults. This study describes the prevalence and correlates of physical activity guideline adherence among a nationally representative sample of German adults. Data were drawn from the 2014 German Health Update survey, collected via a combination of web-based and mail surveys. Self-reported physical activity levels were assessed using the previously validated European Health Interview Survey Physical Activity Questionnaire. Weighted prevalence levels of the sample meeting the aerobic MVPA ( $\geq 150$  minutes/week), MSE ( $\geq 2$  times/week) and combined MVPA-MSE guidelines were calculated. Poisson regressions were used to assess prevalence ratios for physical activity guideline adherence categories across sociodemographic and lifestyle-related variables. Out of 24,016 participants (response rate = 27.6%), aged  $\geq 18$  years, 45.3% (95% CI: 44.5-46.0%), 29.4% (95% CI: 28.7-30.1%) and 22.6% (95% CI: 21.9-23.2%) met the aerobic MVPA, MSE and combined guidelines, respectively. Population sub-groups less likely to meet the combined guidelines included those with poor self-rated health, being unemployed, low socioeconomic status, being a current smoker and those being overweight or obese. Since  $\sim 80\%$  of German adults do not meet the nationally recommended combined aerobic MVPA-MSE physical activity guidelines, there is a necessity for large-scale public health interventions promoting both aerobic MVPA and MSE.

**Key Words:** Public health surveillance, Strength training, aerobic, exercise.

## 1 Background

Globally, approximately three-quarters of deaths are attributable to chronic diseases.<sup>1</sup> In high-income countries, such as Germany, chronic diseases including ischemic heart disease, Alzheimer's disease, stroke and diabetes are the leading causes of mortality and morbidity.<sup>2</sup> Physical inactivity is an independent risk factor for the development of chronic diseases, with epidemiological evidence showing that physical activity decreases the risk of all-cause mortality and the incidence of chronic health conditions.<sup>3</sup>

Since the 1970s, most physical activity guidelines have focused on promoting moderate-to-vigorous aerobic physical activity (MVPA; e.g. walking, cycling, running).<sup>4</sup> More recently, muscle-strengthening exercise (MSE; e.g. resistance exercise/weight training) has been added into global<sup>5</sup> and many national public health guidelines.<sup>6-8</sup> The 2016 German '*National Recommendations for Physical Activity and Physical Activity Promotion*' based on an expert survey and an appraisal of researched studies,<sup>9</sup> was the first German national guidelines to include both aerobic MVPA and MSE. These stated that adults ( $\geq 18$  years) should participate in: [i] at least 150 minutes/week of moderate physical activity (e.g. walking) or 75 minutes/week of vigorous physical activity (e.g. jogging), or an equivalent combination of both; and [ii] 2 or more days per week of MSE involving major muscle groups.<sup>9</sup>

The addition of combined MVPA-MSE into physical activity guidelines is due to the clinical and epidemiological evidence showing each activity mode has independent and cumulative health benefits.<sup>10</sup> In brief, aerobic MVPA is principally associated

with a reduced risk of cardiovascular disease, diabetes, colon/breast cancer and depression.<sup>11</sup> MSE is largely linked to increased skeletal mass/strength, bone density, ability to perform activities of daily living and reduced risk of falls.<sup>12</sup> Also, recent epidemiological studies have shown that compared to meeting one guideline alone, meeting both aerobic MVPA-MSE guidelines is prospectively associated with a lower risk of all-cause mortality.<sup>13,14</sup>

Despite joint aerobic MVPA-MSE being nationally recommended, there is limited available data describing its prevalence and correlates among German adults. German public health surveillance studies have typically solely examined the population-levels of aerobic MVPA guideline adherence,<sup>9</sup> with self-report estimates suggesting that ~50% of adults meet the aerobic MVPA guideline.<sup>15,16</sup> A recent report showed that 29.4% of German adults reported meeting the MSE guideline, and 22.6% met the combined MVPA-MSE guidelines, with guideline adherence declining with age and education and males having a higher prevalence, compared to females.<sup>17</sup> However, limitations of that report were first, physical activity guideline adherence across other key sociodemographic/lifestyle factors was not included (e.g. socioeconomic status, self-rated health, body mass index),<sup>18</sup> and second, a multivariable analysis (including sociodemographic and lifestyle factors) was not conducted. Reporting of physical activity levels by population sub-groups is vital for determining the most ‘at-risk’ populations,<sup>19</sup> and essential to inform/guide optimal public health policy. Moreover, such research could be used to enhance the success of future large-scale physical activity interventions within Germany.

The primary aim of this study is to determine the prevalence of MVPA, MSE and combined MVPA-MSE guideline adherence among a representative sample of German adults. A secondary aim is to examine how physical activity guideline adherence varies across sociodemographic/lifestyle factors.

## **2 Methods**

### *2.1 Sample*

Data were drawn from the 2014 German Health Update (hereafter: GEDA 2014). The GEDA 2014 is a population-based cross-sectional health interview survey conducted on behalf of the Robert-Koch-Institute as part of the German Federal Ministry of Health. Ethics approval for the GEDA 2014 was obtained by the Robert-Koch-Institute and all participants provided informed consent to participate. The purpose of the GEDA is to provide a health monitoring survey that produces reliable information on the actual German adult population's health status, health determinants and health care utilization. <sup>20</sup>

An overview of the methods used in the GEDA 2014 is available elsewhere, <sup>20</sup> Conducted between November 2014 and July 2015, a two-stage stratified cluster sampling approach was used to recruit persons aged  $\geq 18$  years with permanent residence in Germany. Two modes of data collection were used: [i] self-administered web questionnaire (SAQ-Web); and [ii] self-administered paper questionnaire (SAQ-Paper). Initially, 90,102 invitations to participate were sent, with 24,016 fully completed (response rate= 26.9%), with 11,253 via SAQ-Web (45.3%) and 13,571 via SAQ-Paper (54.7%). <sup>17,20</sup>

In the current study, we only included data from those who fully responded to the physical activity items. To increase generalisability, we did not apply any further inclusion/exclusion criteria.<sup>21-24</sup> Additionally, since the German physical activity guidelines for MVPA and MSE apply to both adults (aged 18–64 years) and older adults (aged  $\geq 65$  years),<sup>9</sup> we included adults aged  $\geq 18$  years.

## *2.2 Physical activity (aerobic MVPA and MSE) assessments*

Self-reported physical activity levels were assessed using the European Health Interview Survey Physical Activity Questionnaire (EHIS-PAQ).<sup>25</sup> The EHIS-PAQ is a reliable and valid physical activity assessment tool for use in public health surveillance, and an overview of the development, design and psychometric testing this instrument has been described elsewhere.<sup>25</sup>

### *1. Aerobic MVPA*

Consistent with standardised protocols,<sup>25</sup> to count towards meeting the aerobic MVPA guideline, we included physical activity accrued within the domains of: [i] moderate-to-vigorous aerobic recreational physical activity (e.g. Nordic walking, brisk walking, ball games, jogging, bicycling, swimming, aerobics, rowing, badminton); and [ii] transport-related physical activity (e.g. walking/cycling). For these two domains, respondents were asked to consider physical activity during a ‘typical week’, with the bout of activity having to last for  $\geq 10$  minutes. A validation study showed that when assessing moderate-to-vigorous aerobic recreational and transport-related physical activity, the EHIS-PAQ items have ‘good’ test-retest reliability (Intraclass correlation coefficient [ICC] =0.72-0.73) and fair-to-poor

concurrent validity (Spearman's rank-order correlation =0.36 for transport-related physical activity; and 0.32 moderate-to-vigorous physical activity), using accelerometry as the standard).<sup>26</sup>

Aerobic MVPA levels were calculated for the sample using a previously established scoring protocol.<sup>25</sup> In brief, for transport-related physical activity four items focused on commuting and active traveling to get from one place to another and inquired about the number of days per week and the time per day spent walking and cycling. Minutes per week spent in transportation-related physical activity (in metabolic equivalent [MET] minutes per day) were calculated by summing the minutes spent walking and cycling, each weighted with MET intensity values (i.e., 3.3 for walking and 6.0 for cycling), provided by Ainsworth's physical activity Compendium.<sup>27</sup> For moderate-to-vigorous aerobic recreational physical activity, there was no distinction between moderate and vigorous intensity physical activity, as such, this item refers to all activity as 'at least moderate intensity'. Participants were asked about how many days and the total duration during a typical week they spent in leisure-time sports or fitness pursuits. Minutes per week spent in MVPA were calculated by combining transport-related physical and moderate-to-vigorous aerobic recreational physical activity. Concordant with the German physical activity guidelines, participants were dichotomised as either: [i] 'meeting the aerobic MVPA guidelines' ( $\geq 150$  minutes/week of moderate-to-vigorous-intensity, or [ii] 'not meeting the aerobic MVPA guidelines' (not meeting the above classification).

## *2. Muscle-strengthening exercise*



To assess participation in MSE, respondents were asked, “*In a typical week, on how many days do you carry out physical activities specifically designed to strengthen your muscles such as doing resistance training or strength exercises? Include all such activities even if you have mentioned them before.*”. When considering this question, respondents were prompted to consider a range of MSE-related activities, such as resistance training, strength exercises (using weights, elastic band, own body weight, etc.), knee bends (squats) and push-ups (press-ups). This item has shown to have ‘fair’ test-retest reliability (ICC= 0.55),<sup>25</sup> and similar items have shown evidence of concurrent validity (kappa = 0.52) (using a physical activity log as the standard).<sup>28</sup> According to the German physical activity guidelines,<sup>9</sup> participants were dichotomised as either; [i] ‘meeting the MSE guideline’ ( $\geq 2$  days/week of MSE involving major muscle groups), or [ii] ‘not meeting the MSE guideline’ (not meeting the above classification).

### *3. Meeting the combined MVPA-MSE guidelines*

Consistent with the German public health guidelines,<sup>9</sup> the sample was dichotomised as either: [i] ‘meeting the combined aerobic MVPA-MSE guidelines’ ( $\geq 150$  MVPA minutes/week AND  $\geq 2$  days/week of MSE); or [ii] ‘not meeting the aerobic MVPA-MSE guidelines’ (not meeting the above classification).

### *2.2 Sociodemographic, socioeconomic status and lifestyle variables*

Sociodemographic (sex, age, nationality, socioeconomic status, current life situation) and lifestyle variables (self-rated health, body mass index [BMI], current smoking status) were assessed using standard survey items. Each sociodemographic/lifestyle variable was chosen due to its known association with combined MVPA-MSE,<sup>21-24</sup>

and sub-categories were created to be consistent with previous studies from the GEDA 2014.<sup>29</sup> Socioeconomic status (low, medium or high) was assessed using the previously validated, German-specific, Socioeconomic SES index (SES Index).<sup>29</sup> An overview of the development of the SES Index can be found elsewhere.<sup>29</sup> The SES Index is based on information from three constructs: [i] formal education/vocational training; [ii] occupational status; and [iii] equivalenced to net household income. This index is calculated as a total points score based on the point values assigned to each construct. A distribution-based distinction of three status groups is made for the analyses, with the low and high-status groups each comprising 20% and the medium status group 60% of the population.<sup>29</sup> Self-rated health was assessed on a 5-point scale (1= 'very good' to 5= 'very poor'). BMI was calculated based on self-reported measured height and weight, and categorised into: <18.5 kg/m<sup>2</sup> (underweight); from ≥18.5 kg/m<sup>2</sup> to <25 kg/m<sup>2</sup> (acceptable weight range); from ≥25 kg/m<sup>2</sup> to <30 kg/m<sup>2</sup> (overweight); and ≥30 kg/m<sup>2</sup> (obese).

### *2.3 Statistical analysis*

All statistical analyses were conducted using Complex Sample Module, IBM SPSS 24.0 statistical software (SPSS Inc. an IBM Company, Chicago, IL). To enhance population representativeness, each GEDA 2014 respondent was provided with a sample weight to correct for non-response. Detailed information on the methodological considerations for the sample weights in the GEDA 2014 is available elsewhere<sup>30,31</sup>.

To assess the primary study aim, population-weighted percentages and their 95% confidence intervals (95% CI) were calculated for: [i] meeting the aerobic MVPA

guideline; [ii] meeting the MSE guideline; [iii] meeting both aerobic MVPA-MSE guidelines. Chi-squared tests were used to test the unadjusted differences between the prevalence rates by sociodemographic and lifestyle variables.

To assess the secondary aim, generalized linear models using Poisson regression with robust error variance were conducted to calculate prevalence ratios (PRs) between sociodemographic and lifestyle variables, and: [i] meeting/not meeting aerobic MVPA guideline; [ii] meeting/not meeting the MSE guideline; [iii] meeting/not meeting the combined MVPA-MSE guidelines. Each model included the following explanatory variables: sex (reference group [ref] = “male”); age (ref = “18-29 years”); socioeconomic status (ref = “high”); current life situation (ref: ‘full-time employed’); nationality (ref= “German”); self-rated health (ref = “very good”); BMI (ref = “normal weight”) and current smoking status (ref= ‘non-smoker’). For these Poisson regression analyses, PRs and their 95% CIs were reported.

<<Insert Table 1 here >>

### **3 Results**

Data from 24,016 adults aged were included in the analysis. Socioeconomic and lifestyle characteristics of participants are shown in Table 1. Among the weighted sample, over half were female (51.1%), over one third were aged 45–64 years (36.4%), just under half were full-time employed (47.0%) and the majority were of German nationality (96.4%). Over half rated their health as ‘good’ (53.4%), just

under half had a 'normal' BMI ( $\geq 18.5$  to  $< 25$  kg/m<sup>2</sup>) (51.3%) and over three quarters were non-smokers (77.6%).

A total of 45.3% (95% CI: 44.5%-46.0%) met the aerobic MVPA guideline, 29.4% (95% CI: 28.7%-30.1%) met the MSE guideline and 22.6% (95% CI: 21.9%-23.2%) met the combined aerobic MVPA-MSE guidelines. Except for nationality, significant differences between the proportions meeting all guidelines were observed across the remaining sociodemographic and lifestyle variables ( $p < 0.001$  for all other comparisons) (Table 1).

<<Insert Table 2 here >>

In the Poisson regression, across each sociodemographic and lifestyle factor, the adjusted PRs (APRs) were generally similar for all physical activity guideline adherence categories (Table 2). Compared to men, females had a lower likelihood (APR=0.88; 95% CI: 0.83-0.92) of meeting both guidelines. By age, compared to the youngest respondents (aged 18-29 years), the APRs for meeting both guidelines were lowest among those aged 30-44 years (APR=0.58; 95% CI:0.53-0.63), and similarly lower for those aged 45-64 years and  $\geq 65$  years, respectively. When compared to those who were full-time employed, students were more likely to meet both guidelines (APR=1.73; 95% CI:1.58-1.90), but those who unemployed were less likely to meet both guidelines (APR=0.78; 95% CI:0.68-0.89). Compared to those with German nationality, apart from those as Non-German and not in the European Union being less likely to meet the MVPA guideline (APR=0.83; 95% CI:0.69-0.99), there were no significant differences across the other guideline adherences categories.

The likelihood of meeting each physical activity guideline category decreased by decreasing socioeconomic status and self-rated health. The APRs for both aerobic MVPA-MSE guidelines was lowest among those with ‘very poor’, ‘poor’, and ‘moderate’ self-rated health (APR range =0.20-0.46), and those with ‘low’ socioeconomic status (APR=0.53; 95% CI:0.48-0.59). Compared to those with ‘normal’ BMI, those classified as ‘overweight’ (APR=0.79; 95% CI:0.74-0.84) and ‘obese’ (APR=0.48; 95% CI:0.44-0.83) were 31% and 52% less likely to meet the combined guidelines, respectively.

#### **4 Discussion**

Approximately 80% of German adults did not meet the nationally recommended physical activity guidelines of  $\geq 150$  minutes per week of aerobic MVPA and MSE  $\geq 2$  days per week. Considering that evidence that combined aerobic MVPA-MSE is independently associated with multiple beneficial health outcomes,<sup>13,14,22,32,33</sup> our findings suggest the need for immediate public health action to address physical inactivity in Germany.

The physical activity prevalence estimates (both aerobic MVPA, MSE and combined MVPA-MSE) presented in the current paper suggest that inactivity among German adults is currently underestimated. A recent study based on pooled data from several national public health surveillance surveys worldwide from 2002-2016, stated that 42.2% of German adults ( $\geq 18$  years) were classified as inactive.<sup>15</sup> However, the German data analysed in that study included physical activity estimates solely based

on meeting/not meeting the aerobic MVPA guideline.<sup>15</sup> The present data suggest that when considering the prevalence of adults not meeting the combined MVPA-MSE guidelines (77.4%), physical inactivity among German adults is almost two-fold greater than estimates exclusively based on aerobic MVPA guideline adherence.

The aerobic MVPA guideline adherence estimated in the current study are consistent with previous studies on German adults.<sup>15,16</sup> Cross-country comparisons show that a slightly higher prevalence of German adults meets the combined guidelines compared to the U.S.<sup>22</sup> and U.K.<sup>7</sup> (22.6% vs. ~20.0 %). In contrast, lower MVPA-MSE guideline adherence estimates have been observed among Australian,<sup>24</sup> and Finnish adults<sup>34</sup> (10.8%-15.0%) For MSE guideline adherence, somewhat similar cross-country patterns to those for meeting the MVPA-MSE guidelines have been observed,<sup>22,24,34</sup> with Germany levels comparable to U.S and U.K,<sup>7,23</sup> but higher than those from Australian<sup>24</sup> and Finnish studies.<sup>34</sup>

With the inclusion of a larger number of sociodemographic/lifestyle factors and the use of multivariate-adjusted analysis, the current study expands on a previous report from the GEDA 2014.<sup>17</sup> The lowest likelihood of meeting the combined MVPA-MSE guidelines was identified among those with poorer self-rated health, lower socioeconomic status, the overweight/obese and females. These sociodemographic and lifestyle correlates of combined MVPA-MSE guideline adherence are somewhat congruent with studies from other countries.<sup>21,22,24</sup> For example, similar studies from Australia<sup>24</sup>, Finland<sup>34</sup> and the US<sup>35</sup> have also shown sex differences and inverse income and education gradients for physical activity guideline adherence, and indicate that within the German context, these population sub-groups should be the target for

future physical activity interventions. Being a German national was only significantly associated with meeting the MVPA guideline, and not meeting the MSE or both guidelines. This may suggest that MVPA and MSE may be influenced differently by nationality and hence warrants further study to examine the cause(s) of these inconsistent findings.

A previous study from Germany,<sup>17</sup> and others from Australia, Finland and the U.S. have shown a lower likelihood of meeting the combined MVPA-MSE guidelines with increasing age.<sup>21,22,24</sup> Therefore, it was surprising to observe in our sample of German adults no such age gradient. For example, the second-youngest group (30-44 years) had a lower APR, when contrasted with their older counterparts ( $\geq 45$  years). While somewhat contradictory to studies from Germany and other countries,<sup>17,21,22,24</sup> one German study suggests that physical activity among older populations increases with age – especially for women.<sup>36</sup> While the causes of these mixed findings are yet to be fully established, it might be that older German adults are better informed and more aware of the health benefits of physical activity. This may positively influence being active especially among older populations who are perceiving health problems.

Additionally, children leave the parental home (empty-nest-phase), so especially women have more time resources and sports clubs in Germany offer several activities, which are tailored to women.<sup>36</sup> More research is needed to first, replicate this finding in prospective studies, and second, to determine its causes, especially for the decrease of physical activity in the younger age group. Nonetheless, the age-specific physical activity patterning shown in the current study might be reflective of increasing demands/life commitments encountered as the German population's transition out of young adulthood into middle adulthood.

The finding that ~70% of German adults do not meet the MSE guideline indicates that this physical activity may warrant future national public health attention to increase population-level engagement. Given that MSE is associated with a risk of all-cause mortality<sup>13,14,37</sup>, incidence of diabetes<sup>38,39</sup> and enhanced cardiometabolic health,<sup>40,41</sup> these low MSE prevalence levels are concerning from a public health perspective. However, compared to aerobic MVPA, as with other countries,<sup>23,24,42</sup> the promotion of MSE has been of limited focus in previous Germany public health promotion.<sup>9</sup> Importantly, our study showed that compared to those reporting insufficient aerobic MVPA, greater proportions report insufficient MSE (70.6% vs. 54.7%). Future large-scale public health MSE promotion approaches should include a combination of approaches.<sup>23</sup> Potential simultaneous and multi-level MSE strategies could include; providing physical environmental support (e.g. access to fitness centres/equipment in open spaces),<sup>43</sup> policy support (e.g. subsidizing equipment for home-based activity, gym memberships, access to qualified fitness professionals) and mass-media campaigns challenging the negative stereotypes often linked to MSE (e.g. high injury risk, excessive muscle gain).<sup>44,45</sup>

This study examined only a limited number of the possible correlates of MVPA-MSE. Future studies are needed to examine other potential factors influencing physical activity among German adult populations. Some key influences for further research may include the examination of sociodemographic (marital status, urbanicity etc.), lifestyle (alcohol/diet etc.), psychological (intentions/motivation etc.), social (peer/social support etc.) and environmental factors (location of/access to facilities



etc.).<sup>18</sup> In particular, research on modifiable factors related to MSE will be of interest when developing public health interventions.

A key limitation of this study is the use of self-report MVPA-MSE assessments. We are unable to exclude the possibility this method led to common problems associated with self-report physical activity assessment (e.g. recall bias [over/underreporting], social disability bias and issues around the comprehension of survey items).<sup>46</sup> For example, in the case of aerobic MVPA, compared to accelerometry, the EHIS-PAQ underestimated time spent in with a median difference of 11.7 min/day, which suggests evidence of poor validity. Notwithstanding significant logistical constraints, such as substantial cost and high participant burden, forthcoming German physical activity surveillance studies could consider using accelerometers to assess aerobic MVPA and time-use diaries to assess MSE. Nonetheless, self-report assessments are still the most common method used to assess physical activity among large population samples.<sup>47</sup> The low GEDA 2014 response rate (27.2%) is likely to impact on our MVPA-MSE estimates. Non-responders are probably among the least active populations, and despite the steps to provide accurate survey weighting to correct for non-response, we urge that the physical activity estimates reported here be viewed as conservative.

Strengths of this study include the recruitment of a large national-representative sample of German adults. The GEDA 2014 sample (n=24,016) is approximately 20-fold larger than previous German physical activity prevalence surveys.<sup>48</sup> A further strength was the use of the EHIS-PAQ, a standardised physical activity assessment tool assessing both aerobic MVPA and MSE.

#### *4.1 Perspectives*

Most German adults do not meet the nationally recommended aerobic MVPA-MSE guidelines. These low prevalence levels are concerning from a public health perspective, and highlight that there is a need to provide large-scale physical activity interventions to promote/support both MVPA-MSE uptake and adherence among German adults. Future public health interventions should target those with low socioeconomic status, poor self-rated health, and obese populations.

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#### **Competing interests**

All authors declare that they have no competing interests.

#### **Authors' contributions**

Bennie and Tittlbach conceptualised the study and developed the initial research plan. Bennie conducted the data analysis and drafted the initial manuscript. Tittlbach and De Cocker provided expertise on the analysis and interpretation of data and assisted in

drafting the manuscript. All authors read and approved the final version of the manuscript for publication.

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