Adherence to aerobic and muscle-strengthening components of the physical activity guidelines and mental health

Abstract

Despite clear distinction between aerobic and muscle strengthening (MS) components in the physical activity guidelines, public health surveillance has largely focused only on aerobic components, limiting the reach of epidemiological research on the physical activity guidelines. Hence, this study investigated the association between adherence to both components (i.e., aerobic and muscle-strengthening) of the World Health Organisation's physical activity guidelines and mental health among the college student population. A cross-sectional study was conducted among a nationally representative sample of Irish college students (7,088 participants, M age: 23.17 years; 50.9% female). Participants were categorised as meeting both components of the guidelines (*n*=41%), only the aerobic component (*n*=25.3%) or the MS component (*n*=7.3%), and neither (*n*=26.4%). Group membership effects on mental health was determined through mixed univariate ANOVAs, with a Bonferroni correction for post-hoc analyses to assess multiple comparisons. Results revealed that meeting both components of the guidelines was significantly (all $p < 0.01$) associated with greater self-reported happiness, body image and general health, and less mental ill-being, relative to all other respective groupings. Meeting aerobic or MS components in isolation was significantly ($p < 0.05$) associated with better happiness, general health and body image compared to not meeting either component. To conclude, 59% percent of the college-aged population are insufficiently active, and adherence to both guideline components is positively associated with mental health. Co-produced, evidence-based, physical activity interventions are needed in students, and could contribute to mental health promotion.

Keywords: resistance; exercise; mental illness; well-being; college; higher education.

1.1 Background

Constructed via philosophical traditions and contemporary theories (e.g., Diener & Emmons, 1984; Ryan & Deci, 2000; Ryff, 1989), Keyes' (2002) outlines that well-being constitutes the positive dimension of mental health, whereas depression and anxiety symptoms exist within a distinct, but correlated, ill-being dimension. Ill-being predicts increased risk of illnesses including cardiovascular and Alzheimer's diseases, type 2 diabetes, and reduced mortality (Banatvala et al., 2019). Mental well-being is associated with longevity and healthy functioning (Lawrence, Rogers & Wadsworth, 2015). One in five college (or University/ Third Level) students have? experienced depression or anxiety during a 12-month period (McLafferty et al., 2017), and up to 35% reported low well-being (Shannon et al., 2019). Understanding modifiable lifestyle factors for mental health promotion is therefore important during this? key transitional life stage (Huppert, 2009). Data suggest increases in unhealthy lifestyle behaviours during college years (typically 18-24), including alcohol consumption, smoking and drug use (Nelson et al., 2009; Donohue et al., 2016). Higher rates of overweight/obesity are also evident, along with unhealthy, enduring dietary and sedentary behaviours (Fazzino, Forbush, Sullivan & Befort, 2019). Due to changing body composition during college years (Mcleod, Stokes & Phillips, 2019), body image issues, defined as how one thinks, acts, and feels towards their physical appearance (Radwan et al., 2019) can increase risk to the aforesaid unhealthy behaviours. Physical activity is a modifiable lifestyle behaviour that is comprehensively associated with mental and physical well-being (e.g., Biddle, Gorely & Mutrie, 2014; Way, Hackett, Baker & Johnson, 2016). Indeed, the World Health Organisation (WHO; 2020 and the United Kingdom's Chief Medical's Officer (CMO, 2019) guidance recommends that all adults participate in a minimum of: (i) 150 minutes/week of moderate-intensity (or 75 minutes of vigorous intensity) aerobic physical activity (e.g., walking, running); and (ii) two days per-week of muscle-strengthening (MS) activities (e.g., resistance training).

Despite clear distinction between aerobic and MS components in the guidelines, over the past 45 years public health surveillance has focused only on moderate-to-vigorous aerobic physical activity (MVPA) (Milton et al., 2018; Strain et al., 2019; Bennie, Shakespear-Druery & De Cocker, 2020). For example, most researchers cite that ~27.5% of adults do not meet the WHO guidelines (Guthold, Stevens, Riley, & Bull, 2018). However, this statistic is largely based on the MVPA component alone (Steele et al., 2017), and researchers examining MS activities show that ~66% of adults do not meet the MS component of the guidelines

(Strain, Fitzsimons, Kelly & Mutrie, 2016). Emphasised in a recent review by Bennie et al. (2020), evidence indicates that when assessing MS and aerobic components collectively, between 75-80% of adults do not meet the physical activity guidelines (see, Bennie et al., 2019a; De Cocker, Teychenne, White & Bennie, 2020). Restricted to the college student population, as low as 17.3% (see Branscum & Fairchild, 2019) and as high as 40.3% met both aerobic physical activity and MS recommendations (Wilson et al., 2019). Relatively speaking, while 'complete' guideline adherence is higher among the college student population than the general population, the statistics remain well short of the ideals espoused in the WHO (2020) guidelines.

Beyond prevalence statistics, the European Psychiatric Association (Stubbs et al., 2018), concluded a lack of data and clarity on the association between mental health and MS activities. Some intervention studies (n = 3) indicates independent, but statistically similar effects, for aerobic and MS activities in the treatment of anxiety and depression (Gordon et al., 2017; Gordon et al., 2018). Whereas, recent epidemiological studies among the general population have shown that meeting both guideline components was associated with the lowest risk for depression, anxiety and psychological distress, followed by meeting aerobic, resistance, and not meeting either guideline (Bennie et al., 2018; Oftedal et al., 2019; De Cocker, Teychenne, White & Bennie, 2020).

To date no epidemiological studies examining associations between complete physical activity guideline adherence and mental health have been conducted amongst college students. Furthermore, considered within Keyes' (2002) two-continua model of mental health, existing epidemiological mental health studies among the general population is restricted to the ill-being dimension of mental health (e.g., Bennie et al., 2018; Oftedal et al., 2019), rather than mental well-being, resulting in a limited assessment of a complete mental health model. Lastly, evidence suggests that while physical activity is linked to improved body image, research has focused on aerobic or MS modalities in isolation (SantaBarbara, Whitworth, & Ciccolo, 2017).

As such, two key features emerge from extant literature needing addressed. First, the proportion of college students meeting both, one, or neither components of the physical activity guidelines is inconsistent, with studies often including small, selective samples, and prevalence statistics ranging widely from 17.3% (Branscum & Fairchild, 2019) to as high as 40.3% (Wilson et al., 2019). Establishing prevalence statistics from a nationally

representative sample would provide a more accurate assessment amongst a population already identified at risk of adopting multiple unhealthy lifestyle behaviours. Second, it remains unclear whether independent or combined mental health effects are present for guideline adherence in the college student population. While it would be expected that, as with the general population, MS and aerobic guideline adherence would protect against ill-being, a more holistic model of mental health as theorised by Keyes (2002) would contribute to the current literature. In doing so, subjective elements of mental health such as body image perceptions, a sub-domain of general self-perceptions and linked to self-esteem can be significant (Biddle & Vergeer, 2020), as is subjective well-being, considered within multidimensional mental health models (Longo et al., 2020).

Accordingly, the Student Activity and Sport Study Ireland (SASSI) survey showed associations between adherence to the aerobic component of the physical activity guidelines and health (Murphy et al., 2018). Despite inclusion of a resistance exercise instrument in the survey, adherence to the MS component of the guidelines was not assessed, nor were different combinations of the WHO's (2020) aerobic and MS components of the guidelines[1]. The present study was therefore a secondary analysis of SASSI, aiming to: (i) identify the prevalence of college level students adhering to the WHO's (2020) physical activity guidelines; and (ii) determine whether adherence to different components of the guidelines were associated with fewer self-reported ill-being symptoms (i.e., depressive and anxiety symptoms), better mental well-being, body image perceptions, and self-reported general health.

1.2 Hypotheses tested

For the first study aim, while we expected a majority (>50%) of our sample would not meet both MS and aerobic components, akin to existing studies among the college population (Wilson et al., 2019), we did not formally hypothesise a specific prevalence figure as sample characteristics (e.g., size, cultural norms), likely exert a role. For the second study aim however, and based on emerging epidemiological studies (e.g., Milton et al., 2018; Bennie et al., 2018; Bennie et al., 2019; Oftedal et al., 2019): Hypothesis 1 (H_1) was that, the category meeting both the aerobic MVPA and MS components of the guidelines would score most

[1] Note that Murphy et al.'s (2018) study was conducted across the island of Ireland, which comprises two political jurisdictions with differing guidelines, namely, Republic of Ireland and northern Ireland. The Republic of Ireland's physical activity guidelines do not specify the MS component of the WHO's physical activity guidelines for adults, whilst northern Ireland's does.

favourably on mental health. Secondly, we hypothesised that adherence to the aerobic component alone would predict better mental health than meeting the MS component alone (H_2), and not meeting either component of the guidelines (H_3). Lastly, we hypothesised that adherence to the MS component (H_4) would be associated with better mental health than not meeting either component of the guidelines. Additionally, we controlled for several confounding factors related to mental health including Body Mass Index (BMI), gender, age, alcohol consumption, smoking, illicit drug use and sedentary behaviour (Bauman et al., 2012; Bennie et al., 2019).

2.0 Methods

2.1 Inclusion criteria, recruitment, procedure and participants

This study was a secondary data analysis of phase 2 of SASSI, wherein data were publicly requested by the lead author and granted by the Irish Social Science Data Archive. SASSI was commissioned to understand sport and physical activity participation in colleges/universities across the island of Ireland. To achieve a nationally representative sample, 31 institutions distributed the survey through random sampling that included cohorts who were undertaking undergraduate and postgraduate courses within 10 diverse fields of study (e.g., humanities, social sciences, medicine). Once the sampling framework was applied, 10,606 students were approached for participation. The survey was administered through SurveyMonkey (San Mateo, CA) to entire class groups using an online random number generator that identified the appropriate year group and field of study during a timetabled hour (Murphy et al., 2018).The online survey took approximately 20 minutes to complete and was incentivized by entry into a prize draw that could be exchanged for purchases at a range of retail stores or food outlets. Ethical approval was granted by Ulster University, and endorsed by all participating institutions. Further detail on the methodology for SASSI can be found in Murphy et al. (2019), as can information pertaining to the demographics of the sample.

In total, 9197 survey responses were collected, but following the removal of non-responders, 8122 remained. In the study sample 50.9% were female and were aged on average at 23.17 years (SD=6.75). White European was the most reported ethnicity (91.2%), with other ethnicities including Asian (4.3%), Black (1.9%), mixed/multiple (1.6), and other (1.1%). Participants were mainly undergraduate students (92.4%) enrolled in full-time courses (94.1%), such as Science, Maths and Computing (25.7%), Social Sciences, Business

and Law (21.1%), Humanities and Arts (14.6%) and Health and Welfare (11.8%). Sixty percent of students lived in college accommodation or private residences, with the remaining at their family home.

2.2 Outcome measures

Physical activity guideline adherence/non-adherence

The International Physical Activity Questionnaire-Short Form (IPAQ-SF) (Craig et al., 2003) assessed whether participants met the MVPA component of the WHO's (2020) guidelines. The validity and reliability of the IPAQ-SF (see, Lee et al., 2011) is evident in studies among the student population (Murphy et al., 2017). Using established scoring protocol (IPAQ, 2005), individuals categorised as "high" active were categorised as meeting the aerobic physical activity requirements, with those in "low" or "moderate" comprised the group not adhering (Bauman et al., 2009).

Participation in the MS component of the guidelines was assessed using an instrument from the Sport Participation and Physical Activity Young Adult+ Study (Hardie-Murphy, 2016). Adapted from the IPAQ-SF, the measure is highly similar to existing MS tools in national physical activity surveys showing sound reliability (Yore et al., 2007; Milton et al., 2018). For example, through a 7-day recall period, respondents identify the number of days that were spent doing 'exercises that may strengthen your muscles, such as push-ups, sit-ups, weightlifting or heavy lifting?'. The sample was dichotomised into those meeting (i.e., ≥ 2 days) and not meeting (≤ 1 days) the MS component of the guidelines.

Mental well-being

An item derived from the Northern Ireland Sport and Physical Activity Survey (Sport Northern Ireland, 2010) was used to assess subjective well-being (Diener, 2000). Scored so that 1 represented the lowest (i.e., 'extremely unhappy'), and 10 (i.e., extremely happy) the highest, the tool has been assessed and shown external correlations with various health behaviours (e.g., nutrition, physical activity) in epidemiological studies in Ireland (Breslin, Nevill, Donnelly & Murphy, 2013).

Ill-being symptoms

The five-item Mental Health Inventory (MHI-5) derived from the 36-item medical outcomes health survey (SF-36) (Ware & Sherbourne, 1992) was used to measure ill-being symptoms.

Items were scored on a five-point Likert scale, and inquired about depressive moods (e.g., 'have you felt so down in the dumps that nothing could cheer you up?') and anxiety symptoms (e.g., 'been a very nervous person?'). Previous research has established the validity and reliability of the MHI-5 to positively screen for mood disorders (Rumpf, Meyer, Hapke & John, 2001), and has been shown to be a valid and reliable measure among Irish students (Houghton et al., 2010). Cronbach's alpha among the present sample displayed good internal consistency statistics (a = .80).

Body image

Perceptions of body image were derived through an item from Hart, Leary and Rejeski's (1989) validated and internally reliable social physique anxiety scale. Coded through a Likert scale (i.e., 1= 'much too thin/fat', 2= 'a bit too thin/fat', and 3= 'about the right size'), the item reflects one's satisfaction with body image.

General health

Self-reported general health in the past 12 months was assessed using an item from the SF-36 (Ware & Sherbourne, 1992). Using a 5-point Likert scale, responses were reverse coded so that higher scores equated to better general health (i.e., 5=very good; 1=very poor). The validity and reliability of the SF-36 has been shown among several populations (Laucis, Hays & Bhattacharyya, 2015) and has been used in epidemiological studies in Ireland (Breslin, Nevill, Donnelly & Murphy, 2013).

2.3 Controlling variables

Self-reported BMI ($kg \cdot m^{-2}$) was calculated using WHO (2000) reference values, categorises included: underweight (<18.5), normal weight ($18.5 \leq BMI < 25$), overweight ($25 \leq BMI < 30$), or obese (≥30). Sedentary behaviour was measured via Marshall et al.'s (2010) scale wherein subjects were dichotomised into those sedentary at < 420, or ≥ 420 minutes per-day (Murphy et al., 2018). Items from the Survey of Lifestyle and Attitudes to Nutrition study (Morgan et al., 2007) assessed smoking levels, recreational drug use and alcohol intake.

2.3 Data management and analysis

All outcome variables displayed acceptable skewness and kurtosis values to warrant parametric statistical analyses. The prevalence of physical activity guideline adherence were calculated among the full sample, and split by gender. To test the study hypotheses, a variable positioned each respondent into one of four possible adherence categories: (i) meeting both

guideline components, (ii) meeting aerobic MVPA only, (ii) meeting MS only, and; (iv) not meeting either. Adherence category was included as the independent variable; mental well-being, ill-being symptoms, general health and body image were designated as continuous dependent variables, and; gender, BMI, smoking, sedentary behaviour, drug and alcohol use were specified as fixed controlling factors in several mixed univariate ANCOVA models using SPSS (version 25). Moreover, given the participants were distributed across 31 academic institutions, we included institution as a random factor. Adjusted mean scores and standard errors were reported for the full sample and adherence categories, and statistical significance was set at $p < .05$ (Field, 2013). Third, we used a Bonferroni correction for post-hoc analyses to assess multiple comparisons between adherence categories. Two line figures were produced, in addition to a second table to outline post-hoc group comparisons through unstandardized mean differences, Cohen's *d* effect sizes (n.b., 0.2-0.4= small effect, 0.5-0.7= medium effect, $\geq$.8= large effect), and lower and upper bound confidence intervals were included.

3.0 Results

3.1 Descriptive findings and adherence category effects on study outcomes

After exclusion of 12.7% of the sample who had missing data on at least one guideline component item (*n*=1034), 7088 remained, and 41% self-reported meeting both MS and aerobic components, 25.3% met the aerobic MVPA component only, 7.3% met the MS component only, and 26.4% did not met either component of the guidelines. Therefore, 59% of the sample were deemed insufficiently active through not meeting both guideline components. Split by gender, 52% of males met both guideline components, compared to 29.8% of females. Moreover, 21% of males and 29.8% females met the aerobic component alone, and 7.9% of males and 6.7% of females reported adherence to the MS component alone. Lastly, 19.1% of males and 33.8% of females did not met either component of the guidelines.

After adjusting for statistical controls[2], the corrected model revealed support for the study hypotheses to the extent that the category meeting both guideline components reported the highest well-being levels (see Table 1), with significant results (p <0.01) and small effect

[2] Note that most statistical controls exerted a significant association on the study outcomes, aside from the following; sedentary behaviour on mental ill-being; gender and sedentary behaviour on body image, and; drug use and sedentary behaviour on general health. The random factor (institution) displayed a significant effect in all models. Controlling for these associations, the exposure variable (i.e., physical activity guideline adherence categories) remained significant in the model.

sizes (d=.13 - .34) (H_1). Specifically, while meeting the aerobic component alone was related to better well-being than not meeting either component (H_3), there was no statistically significant difference between adherence to aerobic or MS components in isolation (H_2); nor between meeting MS component alone and not meeting either component (H_4) (see Figure 1 for visual illustration).

Please insert Table 1 and Figure 1

Likewise, Table 2 indicated that the category meeting both guideline components were more likely ($p < 0.001$) to report lower mental ill-being than the other three categories, with small effects (d= .20 - .31; see Figure 2) (H_1). As shown in Figure 2, the category meeting the aerobic MVPA component alone scored lower on ill-being than neither component ($p < .05$) (H_2), yet there was no statistically significant association between the latter comparisons on ill-being ($H_{3,4}$).

Meeting both MS and aerobic components was significantly associated with better body image than the respective categories (H_1) ($p < 0.001$; d= .30-.44). Of note, meeting MS component alone showed better scores for body image than the aerobic component alone ($p < 0.05$; d=.15) (H_2), and not meeting either guideline component ($p < 0.001$; d= .28) (H_4). Meeting the aerobic component alone was associated with a better body image score than not meeting either component ($p < 0.01$; d= .14) (H_3) (see Table 2).

Table 2 also illustrates that meeting both aerobic and MS components was associated with better general perceived health in comparison to the respective categories, with small-to-moderate effect sizes ($p < 0.001$; d=.38-.57) (H_1). Meeting the MS or aerobic components in isolation was also better for perceived general health than not meeting either component ($p < 0.05$, d=.20 and $p < 0.001$, d=.17, respectively) ($H_{3,4}$). There was no significant difference between adherence to MS or aerobic components for perceived general health (H_2).

Please insert Table 2 and Figure 2

4. 0 Discussion

According to our data, approximately 59% of college students are insufficiently active. The 41% meeting the guidelines reported fewer ill-being symptoms, enhanced well-being, body image and general health in comparison to the three respective categories (H_1). Additionally, the 25.3% meeting only the aerobic component of the guidelines displayed better well-being

and general health compared to meeting neither component of the guidelines (H_2), and; the 7.3% meeting the MS component alone scored better general health and body image than meeting neither component (H_4). Hence, our study supports the WHO's (2020) and CMO's (2019) recommendation that, at minimum, adults adhere to both components of the physical activity guidelines for mental health promotion. Results further highlight the need for inclusion and promotion of MS activities alongside aerobic for more robust physical activity surveillance (Bennie et al., 2019a; Bennie, Shakespear-Druery & De Cocker, 2020), and how independent and combined mental health effects are likely present for physical activity modalities (Lubans et al., 2016).

Responding to recent calls (Bennie, Shakespear-Druery & De Cocker, 2020) to address the historical limitations of physical activity and public health epidemiology, the measurement of both guideline components was a pertinent study aim. To illustrate our own shortcomings in regard to providing balance to the guideline assessments, in the first analysis of the SASSI dataset, Murphy et al. (2018) reported that 64.3% of our sample met the physical activity guidelines. We now reveal a markedly lower figure at 41% when both components are measured. A larger sample proportion adhered to both components of the physical activity guidelines than a single in isolation (i.e., 41 compared to 32.6%), and therefore our findings contrast studies among the general population suggesting larger proportions of 'active' individuals engaging in aerobic activities alone (e.g., De Cocker et al., 2020). Further, while a larger proportion of our sample met the guidelines than the general population reported in in Harris et al. (2013) (i.e., 21%), 59% remain insufficiently active. Restricted to the few studies among the college-aged population, our findings are consistent with Wilson et al. (2019) who reported 40% adherence, but higher than Branscum and Fairchild (2019) who indicated 17%. Concerningly, fewer than three in ten of our female participants met both components of the guidelines, and meta-analyses (Corder et al., 2017) show further decreases in physical activity behaviours between the ages of 18-30, and rapid declines during mid-to-late adulthood (Gow, Pattie & Deary, 2017).

Encouragingly, the 41% adhering to both guideline components reported fewer ill-being symptoms, and enhanced well-being, body image and general health (H_1). Moreover, meeting aerobic and MS components in isolation was more advantageous than meeting neither component for perceived general health and body image ($H_{3,4}$), and for well-being via the aerobic component (H_3). Such findings support the view in the United States and Australian guidelines that "doing any physical activity is (likely) better than doing none"

(Teychenne et al., 2020), and a recent meta-analysis (Schuch et al., 2017) showing mental health benefits from lower doses of physical activity. No significant differences existed between aerobic or MS components in isolation on ill-being and well-being, and perceived general health, supporting existing meta-analyses (Gordon et al., 2017; Gordon et al., 2018). A relatively novel finding was that meeting the MS component alone was related to healthier body image than aerobic alone (Santabarbara et al., 2017). Theoretically, MS activities may produce more visible increases in muscular strength and appearance (Nielsen & Thing, 2019). However, and reiterating the need for adherence to both components, meeting both components was related to healthier body image than the respective categories.

Practically, our findings present a contemporary challenge for health authorities, policy makers, and college-level education bodies (Biddle, Gorely and Mutrie, 2014). In terms of our study implications, we propose that our methods offer a template for widescale physical activity surveillance efforts in the college-aged population (see Murphy et al., 2019), and illustrates the importance of inclusion of MS activities. Furthermore, the identification of (i) a majority of inactive students in our data, and (ii) potential benefits of physical activity for mental health in the sample, stresses the urgent need for physical activity interventions among the college-aged population. Recent research (deJonge et al., 2020) among college students suggests a widescale acceptability of physical activity interventions for mental health promotion. However, implementation is hindered due to resourcing, and the education/training of deliverers. For future interventions to be accessible and scalable, logic modelling of socio-ecological factors (e.g., contextual barriers/facilitators, inputs, outputs and impacts) is advised (Mills, Lawton, & Sheard, 2019). A recently developed mental health toolkit for exercise may serve as a guide (see Glowacki et al., 2019).

4.1 Study limitations

As our data were cross-sectional, the relationship between mental health and physical activity is, plausibly, a bi-directional one (e.g., Gucciardi et al., 2020), urging caution on any conclusions drawn from the data. Further, indirect mechanisms (e.g., neurobiological, psychosocial) and effect moderators (e.g., frequency, context, intensity; White et al., 2017), likely driving the salutary association between physical activity on mental health were not tested. Future longitudinal epidemiological research should seek to identify if such factors are implicated in mental health promotion (Teychenne et al., 2020). Moreover, while internally reliable and/or structurally sound, the measures used to assess mental health may have

benefitted from a more comprehensive instrument tapping into multiple well-being theories, such as the mental health continuum short-form (Keyes, 2002). Furthermore, while appropriate for large-scale studies, the self-report nature of our physical activity measurement could have been supplemented with wearable devices (e.g., accelerometers). Lastly, our sample included a diverse range of college students, but was restricted to the Irish context. Further international samples comprising other college institutions would improve the generalisability of the findings.

4.2 Conclusion

In conclusion, we extended physical activity surveillance by determining students' adherence/non-adherence to both components of the WHO's (2014) physical activity guidelines, and; whether independent and/or combined mental health effects were present (Milton et al., 2018). Overall, findings revealed that 59% are insufficiently active, and over one quarter do not meet either guideline component. Consistent with emerging research (e.g., De Cocker et al., 2020) our findings present concern, as the category meeting neither component displayed the poorest mental health profile. However, the 41% meeting both components of the guidelines displayed the most advantageous mental health profile, and meeting one component in isolation was largely better for mental health than not meeting either. Echoing the public health message that some physical activity is likely more beneficial than none (Gordon et al., 2018), we propose the need for investment into guideline awareness, and physical activity interventions among the college-aged population (Daskalopoulou et al., 2017; Steele et al., 2017; Murphy et al., 2018). Future efforts may benefit from designing and/or adapting existing evidence-based physical activity interventions using a co-production model, wherein students exert a role as key stakeholders, and socio-ecological factors are incorporated into the design, implementation and analyses (Mills, Lawton, & Sheard, 2019).

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Figure Captions

Figure 1: Line graph demonstrating differences in mental well-being levels (Y axis) for the four respective group memberships (X axis) based on components of the guidelines adhered/not adhered to

Figure 2: Line graph demonstrating differences in mental ill-being (Y axis) for the four respective group memberships (X axis) based on components of the guidelines adhered/not adhered to.

References

Banatvala, N., Akselrod, S., Webb, D., Sladden, T., Hipgrave, D., & Schneidman, M. (2019). Actions needed to prevent noncommunicable diseases and improve mental health. *Bulletin of the World Health Organization*, *97*(2), 75.

Bauman, A., Bull, F., Chey, T., Craig, C. L., Ainsworth, B. E., Sallis, J. F., & Pratt, M. (2009). The international prevalence study on physical activity: results from 20 countries. International journal of behavioral nutrition and physical activity, 6(1), 21.

Bauman, A. E., Reis, R. S., Sallis, J. F., Wells, J. C., Loos, R. J., Martin, B. W., & Lancet Physical Activity Series Working Group. (2012). Correlates of physical activity: why are some people physically active and others not?. The lancet, 380(9838), 258-271.

Bennie, J., De Cocker, K., Teychenne, M.,. Brown, W., & Biddle,. S (2019). The epidemiology of aerobic physical activity and muscle-strengthening activity guideline adherence among 383,928 U.S. adults. Int J Behav Nutr Phys Act 16, 34 (2019) doi:10.1186/s12966-019-0797-2

Bennie, J. A., Lee, D. C., Khan, A., Wiesner, G. H., Bauman, A. E., Stamatakis, E., & Biddle, S. J. (2018). Muscle-Strengthening Exercise Among 397,423 US Adults: Prevalence, Correlates, and Associations With Health Conditions. American journal of preventive medicine, 55(6), 864-874.

Bennie, J. A., Shakespear-Druery, J., & De Cocker, K. (2020). Muscle-strengthening Exercise Epidemiology: a New Frontier in Chronic Disease Prevention. *Sports medicine-open*, *6*(1), 1-8.

Biddle, S. J., Ciaccioni, S., Thomas, G., & Vergeer, I. (2019). Physical activity and mental health in children and adolescents: An updated review of reviews and an analysis of causality. Psychology of Sport and Exercise, 42, 146-155.

406 Biddle S, Gorely T, Mutrie N (2014). Psychology of physical activity: determinants, well-
407 being and interventions. Milton Park, Abingdon, Oxon; New York, NY: Routledge.

408 Biddle, S. J., & Vergeer, I. (2020). Mental health benefits of physical activity for young
409 people. *The Routledge Handbook of Youth Physical Activity*.

410 Branscum, P., & Fairchild, G. (2019). Differences in determinants of aerobic and muscle
411 strengthening physical activity among college students: a reasoned action approach. *Journal*
412 *of sports sciences*, *37*(1), 90-99.

413 Breslin, G., Nevill, A. M., Donnelly, P., & Murphy, M. H. (2013). Socio-demographic and
414 behavioural differences and associations with happiness for those who are in good and poor
415 health. International Journal of Happiness and Development, 1(2), 142-154.

416 Centers for Disease Control and Prevention. (2018). National Center for Chronic Disease
417 Prevention and Health Promotion, Division of Nutrition, Physical Activity, and Obesity.
418 Data, Trend and Maps [accessed October 31, 2018]. Retrieved from
419 https://www.cdc.gov/nccdphp/dnpao/datatrends-maps/index.html.

420 Chief Medical Officer (2019). UK Chief Medical Officers' Physical Activity Guidelines.
421 Available from:
422 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data
423 /file/829841/uk-chief-medical-officers-physical-activity-guidelines.pdf.

424 Corder, K., Winpenny, E., Love, R., Brown, H. E., White, M., & Van Sluijs, E. (2019).
425 Change in physical activity from adolescence to early adulthood: a systematic review and
426 meta-analysis of longitudinal cohort studies. British journal of sports medicine, 53(8), 496-
427 503.

428 Correll, C. U., Solmi, M., Veronese, N., Bortolato, B., Rosson, S., Santonastaso, P.,. &
429 Pigato, G. (2017). Prevalence, incidence and mortality from cardiovascular disease in patients
430 with pooled and specific severe mental illness: a large-scale meta-analysis of 3,211,768
431 patients and 113,383,368 controls. World Psychiatry, 16(2), 163-180.

432 Craig, C. L., Marshall, A. L., Sjöström, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E.,
433 & Oja, P. (2003). International physical activity questionnaire: 12-country reliability and
434 validity. Medicine & science in sports & exercise, 35(8), 1381-1395.

435 Daskalopoulou, C., Stubbs, B., Kralj, C., Koukounari, A., Prince, M., & Prina, A. M. (2017).
436 Physical activity and healthy ageing: A systematic review and meta-analysis of longitudinal
437 cohort studies. Ageing research reviews, 38, 6-17.

438 De Cocker, Teychenne, White and Bennie (2020). Adherence to aerobic and muscle-
439 strengthening exercise guidelines and associations with psychological distress: A cross-
440 sectional study of 14,050 English adults, Preventive Medicine (139, in press). ISSN 0091-
441 7435

442 deJonge, M. L., Omran, J., Faulkner, G. E., & Sabiston, C. M. (2020). University students'
443 and clinicians' beliefs and attitudes towards physical activity for mental health. Mental
444 Health and Physical Activity, 18, 100316.

Diener, E. (2000). Subjective well-being: The science of happiness and a proposal for a national index. American psychologist, 55(1), 34.

do Amaral Benfica, P., Aguiar, L. T., de Brito, S. A. F., Bernardino, L. H. N., Teixeira-Salmela, L. F., & de Morais Faria, C. D. C. (2018). Reference values for muscle strength: a systematic review with a descriptive meta-analysis. Brazilian journal of physical therapy, 22(5), 355-369.

Donohue, B., Loughran, T., Pitts, M., Gavrilova, Y., Chow, G. M., Soto-Nevarez, A., & Schubert, K. (2016). Preliminary development of a brief intervention to prevent alcohol misuse and enhance sport performance in collegiate athletes. J Drug Abuse, 2(3-10).

Fairman, C. M., Hyde, P. N., & Focht, B. C. (2017). Resistance training interventions across the cancer control continuum: a systematic review of the implementation of resistance training principles. Br J Sports Med, 51(8), 677-685.

Fazzino, T. L., Forbush, K., Sullivan, D., & Befort, C. A. (2019). A Prospective Study of Alcohol Use Patterns and Short-Term Weight Change in College Freshmen. Alcoholism: Clinical and Experimental Research, 43(5), 1016-1026

Gordon, B. R., McDowell, C. P., Lyons, M., & Herring, M. P. (2017). The effects of resistance exercise training on anxiety: a meta-analysis and meta-regression analysis of randomized controlled trials. Sports Medicine, 47(12), 2521-2532.

Gordon, B. R., McDowell, C. P., Hallgren, M., Meyer, J. D., Lyons, M., & Herring, M. P. (2018). Association of Efficacy of resistance exercise training with depressive symptoms: meta-analysis and meta-regression analysis of randomized clinical trials. JAMA psychiatry, 75(6), 566-576.

Glowacki, K., Arbour-Nicitopoulos, K., Burrows, M., Chesick, L., Heinemann, L., Irving, S., & Taylor, A. (2019). It's more than just a referral: Development of an evidence-informed exercise and depression toolkit. Mental Health and Physical Activity, 17, 100297.

Gow, A. J., Pattie, A., & Deary, I. J. (2017). Lifecourse activity participation from early, mid, and later adulthood as determinants of cognitive Aging: the Lothian birth cohort 1921. The Journals of Gerontology: Series B, 72(1), 25-37.

Gucciardi, D. F., Law, K. H., Guerrero, M. D., Quested, E., Thøgersen-Ntoumani, C., Ntoumanis, N., & Jackson, B. (2019). Longitudinal relations between psychological distress and moderate-to-vigorous physical activity: A latent change score approach. Psychology of Sport and Exercise, 101490.

Guthold, R., Stevens, G. A., Riley, L. M., & Bull, F. C. (2018). Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1· 9 million participants. The Lancet Global Health, 6(10), e1077-e1086.

Hart, E. A., Leary, M. R., & Rejeski, W. J. (1989). Tie measurement of social physique anxiety. Journal of Sport and exercise Psychology, 11(1), 94-104.

Hardie Murphy, M., (2016) CSPPA Plus: A 5-year longitudinal study of the children's sport and physical activity participation. Unpublished PhD thesis.

Harris, C. D., Watson, K. B., Carlson, S. A., Fulton, J. E., Dorn, J. M., & Elam-Evans, L. (2013). Adult participation in aerobic and muscle-strengthening physical activities—United States, 2011. MMWR. Morbidity and mortality weekly report, 62(17), 326.

Houghton, F., Keane, N., Murphy, N., Houghton, S., & Dunne, C. (2010). Tertiary level students and the mental health index (MHI-5) in Ireland. Irish Journal of Applied Social Studies, 10(1), 7.

Huppert, F. A. (2009). Psychological well-being: Evidence regarding its causes and consequences. Applied Psychology: Health and Well-Being, 1(2), 137-164.

IPAQ Research Committee. (2005). Guidelines for data processing and analysis of the International Physical Activity Questionnaire (IPAQ)-short and long forms. Accessed (19th November 2019) from: http://www. ipaq. ki. se/scoring. pdf.

Keyes, C. L. (2002). The mental health continuum: From languishing to flourishing in life. Journal of health and social behavior, 207-222.

Lawrence, E. M., Rogers, R. G., & Wadsworth, T. (2015). Happiness and longevity in the United States. Social Science & Medicine, 145, 115-119.

Lee, P. H., Macfarlane, D. J., Lam, T. H., & Stewart, S. M. (2011). Validity of the international physical activity questionnaire short form (IPAQ-SF): A systematic review. International Journal of Behavioral Nutrition and Physical Activity, 8(1), 115.

Laucis, N. C., Hays, R. D., & Bhattacharyya, T. (2015). Scoring the SF-36 in orthopaedics: a brief guide. The Journal of bone and joint surgery. American volume, 97(19), 1628.

Longo, Y., Jovanović, V., Sampaio de Carvalho, J., & Karaś, D. (2020). The general factor of well-being: Multinational evidence using bifactor ESEM on the Mental Health Continuum–Short Form. *Assessment*, *27*(3), 596-606.

Lubans, D., Richards, J., Hillman, C., Faulkner, G., Beauchamp, M., Nilsson, M.,. & Biddle, S. (2016). Physical activity for cognitive and mental health in youth: a systematic review of mechanisms. Pediatrics, 138(3), e20161642.

Marshall, A. L., Miller, Y. D., Burton, N. W., & Brown, W. J. (2010). Measuring total and domain-specific sitting: a study of reliability and validity. Medicine & Science in Sports & Exercise, 42(6), 1094-1102.

McLafferty, M., Lapsley, C.R., Ennis, E., Armour, C., Murphy, S., Bunting, B.P., Bjourson, A.J., Murray, E.K. and O'Neill, S.M. (2017). Mental health, behavioural problems and treatment seeking among students commencing university in Northern Ireland. PloS one, 12(12), p.e0188785.

Mcleod, J. C., Stokes, T., & Phillips, S. M. (2019). Resistance Exercise Training as a Primary Countermeasure to Age-Related Chronic Disease. Frontiers in Physiology, 10, 645.

Morgan K, McGee H, Watson D, Perry I, Barry M, Shelley E, Harrington J, Molcho M, Layte R, Tully N, van Lente E, Ward M, Lutomski J, Conroy R, Brugha R. (2007): Survey of Lifestyle, Attitudes & Nutrition in Ireland: Main Report. Dublin: Department of Health and Children. Accessed 18th November 2019 from: http://epubs.rcsi.ie/psycholrep/3/

Mills, T., Lawton, R., & Sheard, L. (2019). Advancing complexity science in healthcare research: the logic of logic models. BMC medical research methodology, 19(1), 55.

Milton, K., Ramirez Varela, A., Foster, C., Strain, T., Cavill, N., & Mutrie, N. (2018). A review of global surveillance on the muscle strengthening and balance elements of physical activity recommendations. Journal of Frailty, Sarcopenia and Falls, 3(2), 114-124.

Murphy, J.J., Woods, C.B., Murphy, M.H., Murphy, N., Byrne, N. and MacDonncha, C. (2019) 'Student Activity and Sport Study Ireland: Protocol for a Web-Based Survey and Environmental Audit Tool for Assessing the Impact of Multiple Factors on University Students Physical Activity'. *Journal of Medical Internet Research*, 8 (2). https://www.researchprotocols.org/2019/2/e10823

Murphy, J. J., Murphy, M. H., MacDonncha, C., Murphy, N., Nevill, A. M., & Woods, C. B. (2017). Validity and reliability of three self-report instruments for assessing attainment of physical activity guidelines in university students. Measurement in Physical Education and Exercise Science, 21(3), 134-141.

Murphy, M. H., Carlin, A., Woods, C., Nevill, A., MacDonncha, C., Ferguson, K., & Murphy, N. (2018). Active students are healthier and happier than their inactive peers: the results of a large representative cross-sectional study of university students in Ireland. Journal of physical activity and health, 15(10), 737-746.

Nelson MC, Lust K, Story M, Ehlinger E. Alcohol use, eating patterns, and weight behaviors in a University population. Am J Health Behav. 2009;33(3):227–237. PubMed ID: 19063644 doi:10.5993/AJHB.33.3.1

Nielsen, S. F., & Thing, L. F. (2019). 'Who is zooming who'? A study of young PE-students in their figurations. Sport, Education and Society, 24(5), 480-490.

Oftedal, S., Smith, J., Vandelanotte, C., Burton, N. W., & Duncan, M. J. (2019). Resistance training in addition to aerobic activity is associated with lower likelihood of depression and comorbid depression and anxiety symptoms: A cross sectional analysis of Australian women. Preventive medicine, 126, 105773.

Pitt, A., Oprescu, F., Tapia, G., & Gray, M. (2018). An exploratory study of students' weekly stress levels and sources of stress during the semester. Active Learning in Higher Education, 19(1), 61-75.

Radwan, H., Hasan, H. A., Ismat, H., Hakim, H., Khalid, H., Al-Fityani, L., & Ayman, A. (2019). Body Mass Index Perception, Body Image Dissatisfaction and Their Relations with Weight-Related Behaviors among University Students. International journal of environmental research and public health, 16(9), 1541.

Rumpf, H. J., Meyer, C., Hapke, U., & John, U. (2001). Screening for mental health: validity of the MHI-5 using DSM-IV Axis I psychiatric disorders as gold standard. Psychiatry research, 105(3), 243-253.

Ryff, C. D. (1989). Happiness is everything, or is it? Explorations on the meaning of psychological well-being. *Journal of personality and social psychology*, *57*(6), 1069.

SantaBarbara, N. J., Whitworth, J. W., & Ciccolo, J. T. (2017). A systematic review of the effects of resistance training on body image. The Journal of Strength & Conditioning Research, 31(10), 2880-2888.

Schuch, F., Vancampfort, D., Firth, J., Rosenbaum, S., Ward, P., Reichert, T., & Stubbs, B. (2017). Physical activity and sedentary behavior in people with major depressive disorder: a systematic review and meta-analysis. Journal of affective disorders, 210, 139-150.

Shannon, S., Brennan, D., Hanna, D., Younger, Z., Hassan, J., & Breslin, G. (2018). The effect of a school-based intervention on physical activity and well-being: a non-randomised controlled trial with children of low socio-economic status. Sports medicine-open, 4(1), 16.

Shannon, S., Hanna, D., Leavey, G., Haughey, T., Neill, D., & Breslin, G. (2019). The Association Between Mindfulness and Mental Health Outcomes in Athletes: Testing the Mediating Role of Autonomy Satisfaction as a Core Psychological Need. International Journal of Sport and Exercise Psychology (in press).

Sport Northern Ireland. Northern Ireland Sport and Physical Activity Survey (SAPAS) 2010. 2010. http://www.sportni.net/sportni/wpcontent/ uploads/2013/03/SAPASReport.pdf. Accessed November 18th, 2019.

Strain, T., Fitzsimons, C., Kelly, P., & Mutrie, N. (2016). The forgotten guidelines: cross-sectional analysis of participation in muscle strengthening and balance & co-ordination activities by adults and older adults in Scotland. BMC Public Health, 16(1), 1108.

Strain, T., Milton, K., Dall, P., Standage, M., & Mutrie, N. (2019). How are we measuring physical activity and sedentary behaviour in the four home nations of the UK? A narrative review of current surveillance measures and future directions. British journal of sports medicine, bjsports-2018.

Steele, J., Fisher, J., Skivington, M., Dunn, C., Arnold, J., Tew, G., ... & Beedie, C. (2017). A higher effort-based paradigm in physical activity and exercise for public health: making the case for a greater emphasis on resistance training. BMC public health, 17(1), 300.

Stubbs, B., Vancampfort, D., Hallgren, M., Firth, J., Veronese, N., Solmi, M., & Schmitt, A. (2018). EPA guidance on physical activity as a treatment for severe mental illness: a meta-review of the evidence and Position Statement from the European Psychiatric Association (EPA), supported by the International Organization of Physical Therapists in Mental Health (IOPTMH). European Psychiatry, 54, 124-144.

Student Sport Ireland (2017). Student Activity and Sports Study Ireland (SASSI), 2014-2015. [dataset]. 1st Edition. Irish Social Science Data Archive. SN:0054-00. ucd.ie/issda/sassi

Swift, D. L., McGee, J. E., Earnest, C. P., Carlisle, E., Nygard, M., & Johannsen, N. M. (2018). The effects of exercise and physical activity on weight loss and maintenance. Progress in cardiovascular diseases, 61(2), 206-213.

Thorley, G. (2017). Not by Degrees: Improving student mental health. Institute for Public Policy Research. Available from: https://www.ippr.org/files/2017-09/1504645674_not-by-degrees-170905.pdf.

Teychenne, M., White, R. L., Richards, J., Schuch, F. B., Rosenbaum, S., & Bennie, J. A. (2020). Do we need physical activity guidelines for mental health: What does the evidence tell us?. Mental Health and Physical Activity, 18, 100315.

Villareal, D. T., Aguirre, L., Gurney, A. B., Waters, D. L., Sinacore, D. R., Colombo, E., ... & Qualls, C. (2017). Aerobic or resistance exercise, or both, in dieting obese older adults. New England Journal of Medicine, 376(20), 1943-1955.

Ware Jr, J. E., & Sherbourne, C. D. (1992). The MOS 36-item short-form health survey (SF-36): I. Conceptual framework and item selection. Medical care, 473-483.

Way, K. L., Hackett, D. A., Baker, M. K., & Johnson, N. A. (2016). The effect of regular exercise on insulin sensitivity in type 2 diabetes mellitus: a systematic review and meta-analysis. Diabetes & metabolism journal, 40(4), 253-271.

Wilson, O. W., Papalia, Z., Duffey, M., & Bopp, M. (2019). Differences in college students' aerobic physical activity and muscle-strengthening activities based on gender, race, and sexual orientation. *Preventive medicine reports*, *16*, 100984.

White, R. L., Babic, M. J., Parker, P. D., Lubans, D. R., Astell-Burt, T., & Lonsdale, C. (2017). Domain-specific physical activity and mental health: a meta-analysis. American journal of preventive medicine, 52(5), 653-666.

Woods, C., Moyna, N., Quinlan, A., Tannehill, D., & Walsh, J. (2010). The Children's Sport Participation and Physical Activity study (CSPPA study). Research report no. 1. School of Health and Human Performance, Dublin City University and The Irish Sports Council, Dublin, Ireland, 26–108

World Health Organization. (2000). Obesity: preventing and managing the global epidemic (No. 894). World Health Organization, Geneva.

World Health Organization (2014). http://www. who. int/mediacentre/factsheets/fs340/en. url> http://www.who.int/mediacentre/factsheets/fs241/en/</url 2014.

World Health Organization. (2020). WHO guidelines on physical activity and sedentary behaviour: at a glance. Accessed (06/2021) from: https://apps.who.int/iris/bitstream/handle/10665/337001/9789240014916-ara.pdf

Yore, M. M., Ham, S. A., Ainsworth, B. E., Kruger, J., Reis, J. P., Kohl 3rd, H. W., & Macera, C. A. (2007). Reliability and validity of the instrument used in BRFSS to assess physical activity. *Medicine and science in sports and exercise*, *39*(8), 1267-1274.