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

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Summary

Despite a 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 Organization'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 (7088 participants, *M* age: 23.17 years; 50.9% female). Participants were categorized 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% 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

BACKGROUND

Constructed via philosophical traditions and contemporary theories (e.g. [Diener and Emmons, 1984; Ryff, 1989; Ryan and Deci, 2000]), Keyes' (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 an 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 *et al.*, 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 *et al.*, 2019). Due to changing body composition during college years (McLeod *et al.*, 2019), body image issues, defined as how one thinks, acts, and feels towards their physical appearance (Radwan *et al.*, 2019) can increase the risk of the aforesaid unhealthy behaviours. Physical activity is a modifiable lifestyle behaviour that is comprehensively associated with mental and physical well-being (e.g. [Biddle *et al.*, 2014; Way *et al.*, 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 min/week of moderate-intensity (or 75 min of vigorous intensity) aerobic physical activity (e.g. walking, running); and (ii) 2 days per-week of muscle-strengthening (MS) activities (e.g. resistance training).

Despite the clear distinction between aerobic and MS components in the guidelines, over the past 45 years public health surveillance has focused on moderate-to-vigorous aerobic physical activity (MVPA) (Milton *et al.*, 2018; Strain *et al.*, 2019; Bennie, Shakespear-Druery and De Cocker, 2020). For example, most researchers cite that ~27.5% of adults do not meet the WHO guidelines (Guthold *et al.*, 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 *et al.*, 2016). As emphasized in a recent review by Bennie *et al.* (Bennie *et al.*, 2020), evidence indicates that when assessing MS and aerobic components collectively, between 75% and 80% of adults do not meet the physical activity guidelines (see, Bennie *et al.*, 2019; De Cocker *et al.*, 2020). Restricted to the college student population, as low as 17.3% (see Branscum and 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 (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 *et al.*, 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' (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 holistic 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 *et al.*, 2017).

As such, two key features emerge from extant literature needing to be 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 and 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 of a population already identified as 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 theorized by Keyes (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 and 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 the 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 (WHO, 2020) aerobic and MS components of the guidelines. Note that Murphy *et al.*'s (Murphy *et al.*, 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 did not specify the MS component of the WHO's physical activity guidelines for adults, whilst northern Ireland's did. 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 (WHO, 2020) physical activity guidelines; and (ii) determine whether adherence to different components of the guidelines was 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.

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 hypothesize a specific prevalence figure as sample characteristics (e.g. size, cultural norms), likely exert a role. For the second study's aim, however, and based on emerging epidemiological studies (e.g. [Bennie *et al.*, 2018, 2019; Milton *et al.*, 2018; 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 favourably on mental health. Secondly, we hypothesized 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 hypothesized 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).

METHODS

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 the 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 min 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.* (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 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 in their family homes.

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 (WHO, 2020) guidelines. The validity and reliability of the IPAQ-SF (see, Lee *et al.*, 2011) are evident in studies among the student population (Murphy *et al.*, 2017). Using established scoring

protocol (IPAQ, 2005), individuals categorized as 'high' active were categorized 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 sports 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 dichotomized into those meeting (i.e. ≥ 2 days) and not meeting (≤ 1 days) the MS component of 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 et al., 2013).

Ill-being symptoms

The five-item Mental Health Inventory (MHI-5) derived from the 36-item medical outcomes health survey (SF-36) (Ware and 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 et al., 2001), and is a valid and reliable measure among Irish students (Houghton et al., 2010). Cronbach's alpha among the present sample displayed good internal consistency statistics ($\alpha = 0.80$).

Body image

Perceptions of body image were derived through an item from Hart et al. (Hart et al., 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 and 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 have been shown among several populations (Laucis et al., 2015) and have been used in epidemiological studies in Ireland (Breslin et al., 2013).

Controlling variables

Self-reported BMI ($\text{kg}\cdot\text{m}^{-2}$) was calculated using WHO (WHO, 2000) reference values, categories included: underweight (< 18.5), normal weight ($18.5 \leq \text{BMI} < 25$), overweight ($25 \leq \text{BMI} < 30$), or obese (≥ 30). Sedentary behaviour was measured via Marshall et al.'s (Marshall et al., 2010) scale wherein subjects were dichotomized into those sedentary at < 420 , or ≥ 420 min 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.

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 was 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, (iii) 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 institutions 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 $p < 0.05$ (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, ≥ 0.8 = large effect), and lower and upper bound confidence intervals were included.

RESULTS

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 meet 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% of 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 meet either component of the guidelines.

After adjusting for statistical controls (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.), 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 sizes ($d = 0.13$ – 0.34) (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 the MS component alone and not meeting either component (H_4) (see [Figure 1](#) for visual illustration).

Table 1: Corrected model adjusted mean scores and standard errors for the study outcomes, split by guideline adherence groupings, and full sample

PA guideline adherence category	Well-being	Mental ill-being	Body image	General health
Neither component	6.05 (0.12)	59.79 (1.10)	1.92 (0.03)	3.12 (0.05)
Both components	6.62 (0.12)	64.32 (1.10)	2.14 (0.03)	3.55 (0.05)
MS only	6.02 (0.15)	60.57 (1.37)	2.07 (0.04)	3.25 (0.06)
Aerobic only	6.30 (0.12)	61.67 (1.11)	1.99 (0.03)	3.25 (0.05)
Full sample	6.22 (0.11)	60.96 (.99)	2.04 (0.03)	3.28 (0.05)

Likewise, [Table 2](#) indicates that the category meeting both guideline components was more likely ($p < 0.001$) to report lower mental ill-being than the other three categories, with small effects ($d = 0.20$ – 0.31 ; 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 ($p < 0.05$) (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) ($p < 0.001$; $d = 0.30$ – 0.44). Of note, meeting MS component alone showed better scores for body image than the aerobic component alone ($p < 0.05$; $d = 0.15$) (H_2), and not meeting either guideline component ($p < 0.001$; $d = 0.28$) (H_4). Meeting the aerobic component alone was associated with a better body image score than not meeting either component ($p < 0.01$; $d = 0.14$) (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 ($p < 0.001$; $d = 0.38$ – 0.57) (H_1). Meeting the MS or aerobic components in isolation was also better for perceived general health than not meeting either component ($p < 0.05$, $d = 0.20$ and $p < 0.001$, $d = 0.17$, respectively) ($H_{3,4}$). There was no significant difference between adherence to MS or aerobic components for perceived general health (H_2).

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 (WHO, 2020) and CMO's (CMO, 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.*, 2019; Bennie *et al.*, 2020), and how independent and combined mental health effects are likely to present for physical activity modalities (Lubans *et al.*, 2016).

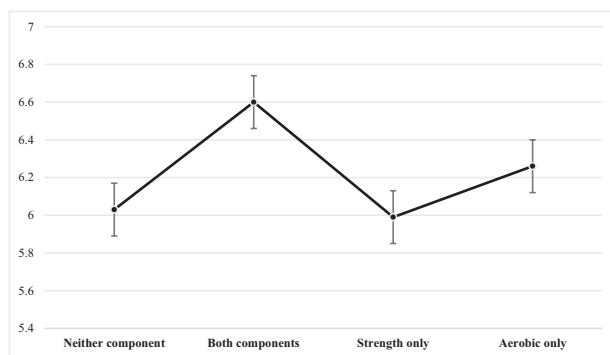


Fig. 1: Line graph demonstrating differences in mental well-being levels (Y axis) for the four respective group memberships (X axis) based on components of the guidelines adhered/not adhered to.

Responding to recent calls (Bennie *et al.*, 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.* (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 Harris *et al.* (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.* (Wilson *et al.*, 2019) who reported 40% adherence but higher than Branscum and Fairchild (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.*, 2019) show further decreases in physical activity behaviours between the ages of 18–30, and rapid declines during mid-to-late adulthood (Gow *et al.*, 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 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 aerobics alone (Santabarbara *et al.*, 2017). Theoretically, MS activities may produce more visible increases in muscular strength and appearance (Nielsen and Thing, 2019). However, and reiterating the need for adherence to both components, meeting both components was related to a healthier body image than the respective categories.

Practically, our findings present a contemporary challenge for health authorities, policymakers, and college-level education bodies (Biddle *et al.*, 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 illustrate the importance of the 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 *et al.*, 2019). A recently developed mental health toolkit for exercise may serve as a guide (see Glowacki *et al.*, 2019).

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 and 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

Table 2: Model adjusted unstandardized mean score differences and Bonferroni adjusted *post hoc* comparisons for the group membership on study outcomes

Outcome	Guideline adherence group	Comparison	Mean difference	SE	Cohens <i>d</i>	Lower bound CIs	Upper bound CIs
Happiness	Neither component	Both	-0.56*	0.07	0.33	-0.757	-0.37
		Strength only	0.04	0.12	0.01	-0.269	0.344
		Aerobic only	-0.24*	0.08	0.13	-0.447	-0.031
	Both components	Strength only	0.60*	0.11	0.34	0.307	0.895
		Aerobic only	0.32*	0.07	0.19	0.129	0.519
		Strength only	Aerobic only	-0.28	0.12	0.14	-0.586
Mental ill-being	Neither component	Both	-4.53*	0.69	0.31	-6.343	-2.713
		Strength only	-0.78	1.09	0.07	-3.651	2.100
		Aerobic only	-1.88	0.74	0.11	-3.827	0.066
	Both components	Strength only	3.75*	1.04	0.24	0.997	6.508
		Aerobic only	2.65*	0.69	0.20	0.821	4.474
		Strength only	Aerobic only	-1.11	1.10	0.04	-4.004
Body image	Neither component	Both	-0.21*	0.02	0.44	-0.268	-0.16
		Strength only	-0.14*	0.03	0.28	-0.227	-0.056
		Aerobic only	-0.07*	0.02	0.14	-0.125	-0.009
	Both components	Strength only	0.07	0.03	0.15	-0.009	0.155
		Aerobic only	0.15*	0.02	0.30	0.092	0.201
		Strength only	Aerobic only	0.07	0.03	0.15	-0.012
General health	Neither component	Both	-0.43*	0.03	0.57	-0.514	-0.344
		Strength only	-0.14*	0.05	0.20	-0.269	-0.002
		Aerobic only	-0.14*	0.03	0.17	-0.227	-0.045
	Both components	Strength only	0.30*	0.05	0.38	0.165	0.422
		Aerobic only	0.29*	0.03	0.39	0.208	0.379
		Strength only	Aerobic only	0.00	0.05	0.02	-0.135

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 generalizability of the findings.

CONCLUSION

We extended physical activity surveillance by determining students' adherence/non-adherence to both components of the WHO's (WHO, 2015) 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

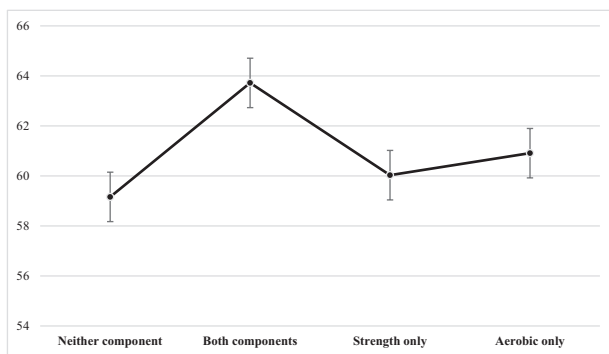


Fig. 2: Line graph demonstrating differences in mental ill-being (Y axis) for the four respective group memberships (X axis) based on components of the guidelines adhered/not adhered to.

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 in 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 *et al.*, 2019).

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Ethical Approval

Ethical approval was granted by Ulster University and recognized by all participating institutions.

Conflict of Interest

All authors confirm that we have no conflict of interest to declare.

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