Can physical activity be simplified for health benefit?

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ABSTRACT

AIM: Physical activity (PA) offers protective benefits against at least 25 chronic conditions including psychological stress. The health benefits of PA may be largely attributed to improvements in cardiorespiratory fitness (CRF). However, current guidelines based on PA duration and intensity are controversial, and both are prone to measurement error. We designed a New Zealand specific physical activity frequency and type (PAFT) question, our aims were to examine if PAFT could predict CRF and psychological stress status.

METHODS: In experiment one, 20 subjects who regularly performed vigorous type PA completed PAFT prior to World Health Organization (WHO) recommended cardiorespiratory fitness (CRF) (VO$_{2\text{Peak}}$) estimation in a controlled exercise laboratory. In experiment two, 81 subjects completed PAFT and a reliable validated measure of stress (the ten-item Perceived Stress Scale (PSS-10)).

RESULTS: Vigorous type PA frequency had a strong association ($R^2 = 0.71$, $p<0.01$) with VO$_{2\text{Peak}}$ and was also the most significant ($p<0.01$) predictor of low stress.

CONCLUSIONS: A simple quick PA type and frequency question predicts CRF and stress status. PA duration and intensity are not required to estimate the health benefits of PA. Two vigorous type PA activities per week can be recommended as a minimum PA dose to decrease risk of stress in similar populations.

Physical activity (PA) imparts clear health benefits and reduces risk (20–30%) of 25 or more chronic physical and mental health conditions.\textsuperscript{1–3} PA is multi-faceted and can be characterised by several components: type, frequency, duration and intensity. There is a lack of knowledge and much controversy regarding how individual PA components combine to influence health. As weekly PA duration increases, all-cause mortality risk decreases in a non-linear relationship.\textsuperscript{2–4} However, PA duration and risk varies by condition: 500 minutes of moderate intensity PA per week appears to be required for the largest observed decrease in cardiovascular disease risk, while greater than 1,200 minutes at the same PA intensity is required for the largest observed decrease in all-cancer risk.\textsuperscript{4} While long PA duration is associated with the lowest mortality risk, the largest risk reduction is paradoxically observed at very low PA duration.\textsuperscript{2,4} Essentially, the largest health benefit from PA is observed when “doing nothing” is compared with “doing something”. One such benefit of regular PA is that it decreases psychological stress,\textsuperscript{5} which can be defined as an individual’s perception that their own personal capacity to cope with their environmental demands has been exceeded.\textsuperscript{6} Psychological stress is itself associated with many physical diseases,\textsuperscript{6} and in New Zealand psychological distress measures are worsening.\textsuperscript{7} Psychological distress measures have also been recently compounded by the COVID-19 pandemic.\textsuperscript{8} During COVID-19 restrictions, those who reported a reduction in PA behaviour reported significantly poorer mental health and wellbeing in New Zealand.\textsuperscript{8} PA advice that can be provided to reduce and/or limit stress and other health conditions is important for health in New Zealand.

The health-related components of physical fitness are cardiorespiratory fitness (CRF), muscular endurance, muscular strength, body composition and flexibility.\textsuperscript{9} While all components are important, CRF has recently become the most valid vital sign for general health and function.\textsuperscript{3,10,11} CRF is reliant on the contemporaneous performance of the respiratory, cardiovascular and musculoskeletal systems. When compared with traditional risk factors, CRF is the best single predictor of health outcomes in both healthy and clinical populations.\textsuperscript{3,11} The World Health Organization (WHO) have long recommended cardiopulmonary exercise testing (CPX) as the gold standard method to assess CRF, as it allows direct measurement of VO$_{2\text{Peak}}$.\textsuperscript{12} However, this is labour intensive, requiring a specialist exercise laboratory with advanced gas analysis equipment, trained personnel and subjects motivated to exercise until exhaustion. VO$_{2\text{Peak}}$ can also be estimated via self-report questionnaires, which are a common method of measuring PA. However, when used to classify...
subjects into just three CRF categories determined by the gold standard method, questionnaires will misclassify approximately half of all individuals.\textsuperscript{13} This may be related to the quality of assessing PA duration and intensity from questionnaires which is particularly prone to error.\textsuperscript{14} There is a need for self-reporting PA instruments that demonstrate good agreement with gold standard VO\textsubscript{2Peak}.

PA guidelines for health in New Zealand are based on PA duration and intensity.\textsuperscript{15} The guidelines recommend a minimum weekly PA dose of 150 minutes of moderate, or 75 minutes of vigorous, PA, and suggest aiming for 300 minutes of moderate, or 150 minutes of vigorous, PA for “extra health benefits”. In contrast, the WHO\textsuperscript{16} recommend that extra health benefits only occur at greater durations than these. PA duration and intensity differences are also apparent in recommendations from 23 European Union countries.\textsuperscript{17} While all official guidelines contain a minimum weekly duration PA recommendation, these lack a robust evidence base. PA durations substantially below official recommendations show health benefits.\textsuperscript{2,4} Many guidelines also recommend a minimum timeframe (often 10–15 minutes) for a single PA bout.\textsuperscript{17} However, recent evidence suggests shorter duration single PA bouts are equally effective.\textsuperscript{18} PA intensity is the most controversial of all PA components. Firstly, even highly objective PA intensity measurements such as the same percentages of VO\textsubscript{2Peak} or maximal heart rate result in substantially different individual metabolic and cardio-circulatory responses.\textsuperscript{19} Secondly, improving VO\textsubscript{2Peak} is shown to be possible from PA sessions that use a single 20–30 second bout at very high (sprint) intensity, and the largest improvements may occur with fewer (2–3) such bouts compared with more bouts per session.\textsuperscript{20} Official PA guidelines are thus questionable, and may even be counter-productive by creating unnecessary barriers for some individuals.\textsuperscript{12} For many health outcomes in many populations, PA type, frequency, duration and intensity thresholds to offer benefit remain unclear.

Current PA questionnaires are limited because they demonstrate particularly poor agreement with VO\textsubscript{2Peak} (R\textsuperscript{2}=0.25–0.70).\textsuperscript{13} As PA duration and intensity are both controversial and particularly prone to bias from questionnaires, we sought to examine if PA type and frequency alone could be useful to estimate CRF and health. We aimed to take a single question from a validated and reliable questionnaire, modify the PA types to match our local New Zealand populations PA preferences, and then to test the question. Specifically, we aimed to examine the associations between PA type and frequency data obtained from this one question with gold standard VO\textsubscript{2Peak} and perceived stress. If such a question can predict VO\textsubscript{2Peak} and stress, it may provide a simple guide for monitoring CRF and health in New Zealand populations. Additionally, it may encourage further research in designing a PA questionnaire that can reliably estimate VO\textsubscript{2Peak}.

Material and methods

Physical activity frequency and type (PAFT) question

Question two from the validated and reliable five item physical activity questionnaire\textsuperscript{23} was modified for the categories of PA. The categories of PA were initially chosen from the long forms of validated New Zealand Physical Activity Questionnaire (NZPAQ-LF). Categories were then refined during a test of the questionnaire on a small sample of 10 local residents. Five categories were moderate intensity PA and five were vigorous intensity PA, as defined by New Zealand guidelines. The final question contained 11 categories of PA. Each category uses a five-point Likert scale, categorised as “7 or more times/week”, “5–6 times/week”, “3–4 times/week”, “1–2 times/week”, and “0 times/week”. The last category was the number of days per week with no PA, which also served as a cross-check answer validity check. The 11 categories of PA are scored as 7, 5.5, 3.5, 1.5 and 0, respectively. The sum of the first 10 items is used to calculate a total PA frequency score (PAF\textsubscript{all}), a measure of total weekly moderate and vigorous PA frequency. A total PA vigorous score (PAF\textsubscript{vig}) was also calculated from the sum of the five vigorous PA activities. PAF\textsubscript{all} is the number of total vigorous PA activities per week. The units for PAF\textsubscript{all} and PAF\textsubscript{vig} are activities per week (AW). Activity days were also recorded as the reverse score of the last category.

Experiment 1

PAFT as a predictor of VO\textsubscript{2Peak}

PAFT was completed by 20 subjects immediately prior to VO\textsubscript{2Peak} testing. The cohort consisted of males (n=16), and females (n=4). Inclusion criteria of subjects were a resident of Hawkes Bay, willing and capable of performing VO\textsubscript{2Peak} testing to exhaustion and free from injury and illness, and who was regularly performing vigorous style PA. Subjects completed a maximal cycling
or running test dependent upon their personal preference. All testing was conducted in an environmentally controlled laboratory (temperature 20±2°C: relative humidity 36±4%). Prior to testing all subjects completed a 10 minute warm-up at a self-selected submaximal intensity.

Runners completed the test using a motorised treadmill (Cosmos pulsar 3p) with a gradient fixed at 1%. The maximal incremental test commenced at 8km/h and increasing by 1km/h each minute until subjects reached volitional exhaustion.

Cycling tests were performed on a calibrated Velotron Dynafit Pro cycle ergometer (RacerMate Inc., WA, USA). Subjects completed a maximal incremental test commencing at 75W with power output increasing at a rate of 25W·min⁻¹ until the cyclist reached volitional exhaustion.

All participants achieved minimum test duration of eight minutes. Respiratory gases were continuously measured with a metabolic cart (Metalyser 3B, Cortex, Leipzig, Germany) calibrated in accordance with the manufacturer’s instruction using Alpha gas standards. \( VO_{2\text{peak}} \)

was determined as the highest 30s oxygen uptake value recorded during the incremental test.

**Experiment 2 PAFT as a predictor of perceived stress**

Experiment two subjects were invited to participate in this study via posters and social media placed at the lead researchers’ tertiary institution between February 2019 and December 2019. All subjects who consented completed the PAFT question followed with the ten item perceived stress scale (PSS-10). Exclusion criteria were (1) a current residential address other than Hawkes Bay, (2) any data missing on any question on either of the two questionnaires, and (3) a lack of agreement between the first 10 categories of PA and the last reverse scored PA category. The PSS-10 is a validated tool to measure perceived psychological stress over the preceding four weeks in many populations.²³ The PSS-10 was used to calculate a stress score as previously described. Individual PSS-10 scores within the 0–13 range are considered low stress, the 14–26 range is considered moderate stress, while over 27 is considered high perceived stress.

**Statistics**

All variables were tested for Gaussian distributions with D’Agostino-Pearson normality omnibus K2 test to determine parametric statistic suitability. Correlation and regression were both performed to establish the relationship between \( VO_{2\text{peak}} \) and \( PAF_{\text{All}} \) \( PAF_{\text{Vig}} \) and activity days. One way ANOVA followed by post hoc Tukey was used in the following comparisons: (1) subjects were divided into low moderate and high stress groups (see PSS-10 above) and compared for age, activity days, \( PAF_{\text{All}} \) \( PAF_{\text{Vig}} \), and (2) subjects were compared for PSS across four groups based on the number of days of exercise per week (7 days, 6 or 5 days, 4 or 3 days and 2 or fewer days). The unpaired t-test was used in the following comparisons: (1) tertiary students were compared with non-tertiary students for age, activity days, \( PAF_{\text{All}} \) and \( PAF_{\text{Vig}} \), Low stress and high/moderate stress groups were examined for association using Pearson’s Chi-squared test for identifying as a tertiary student or a specific gender. Receptor operating characteristic (ROC) analysis was used to examine if PSS could be predicted by activity days, \( PAF_{\text{All}} \) \( PAF_{\text{Vig}} \) The data was analysed and graphs constructed using Prism (Prism, Version 4.0 GraphPad Software, San Diego, CA, USA, www.graphpad.com).

**Ethical approval**

This study was approved by the local Research Committee on 11/12/2018 Reference (REF 18/17).

**Results**

**Experiment one**

Twenty subjects (mean ± SD age 41±8y; weight 72±11kg; height 176±11cm) volunteered for maximal aerobic testing and competed PAFT. \( PAF_{\text{Vig}} \) scores (mean ± SD age 5.9±2.8) correlated \((r=0.68, p=0.002)\) with \( VO_{2\text{peak}} \) (mean ± SD 57.5±9.1ml.kg⁻¹), while \( PAF_{\text{All}} \) did not. Activity days also correlated \((r=0.71, p=0.002)\) with \( VO_{2\text{peak}} \); however, 65% of these subjects all recorded five or six days of activity per week limiting interpretation. A curvilinear relationship (Figure 1) best described the \( VO_{2\text{peak}} \) \( PAF_{\text{Vig}} \) association.

**Experiment two**

Eighty-seven subjects initially completed both PSS and PAFT. Six subjects were excluded as \( PAF_{\text{All}} \) or \( PAF_{\text{Vig}} \) were incompatible with activity days. Correlations between activity days and \( PAF_{\text{All}} \) \((r=0.55, p<0.001)\) and \( PAF_{\text{Vig}} \) \((r=0.40, p<0.001)\) provided a measure of cross-check answer validity. Tertiary students (n=44) compared with non-students were younger \((p<0.001)\) (mean ± SD years 27.4±8.5 vs 45.5±14.5), reported greater \((p<0.001)\) stress \((20.7±5.6 vs 12.2±7.5)\) less \((p=0.004)\) activ-
ity days (1.2±1.5 vs 2.3±1.9), lower (p=0.001) PAF$_{\text{All}}$ (6.5±4.7 vs 11.4±6.7), and lower (p=0.001) PAF$_{\text{Vig}}$ (6.5±4.7 vs 11.4±6.7). See Table 1.

To examine associations with categorical variables, high and moderate stress groups were combined into one higher stress group because a lack of subjects with high stress (n=8) prevented meaningful statistical analysis. Only identifying as a tertiary student (p<0.001, Chi-squared=34.72) was positively associated with higher stress.

PAF$_{\text{All}}$ and PAF$_{\text{Vig}}$ were examined as predictors of PSS using linear regression. PAF$_{\text{All}}$ ($R^2=0.09$, p=0.009) and PAF$_{\text{Vig}}$ ($R^2=0.12$, p=0.002) explained only approximately 10% of the variance in PSS scores. Activity days was associated with perceived stress (Figure 2).

Figure 1: Maximal oxygen consumption vs PAF$_{\text{Vig}}$ (n=20).

Activity days (the number of days subjects performed a minimum of one session of physical activity per week) are compared for PSS Score. Lines are Mean and 95% CI. Post hoc analysis (Tukey’s Multiple Comparison Test) revealed only 7 days vs 3 or 4 days (p<0.01) and 7 days vs 2 or fewer days (p<0.01) were different between groups.

Table 1: ANOVA results from subjects grouped by stress level.

<table>
<thead>
<tr>
<th></th>
<th>One way ANOVA results</th>
<th>Low stress (n=30)</th>
<th>Moderate stress (n=43)</th>
<th>High stress (n=8)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>p</td>
<td>F</td>
<td>Mean</td>
<td>Std. dev.</td>
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<tr>
<td>Subject age (y)</td>
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<td>12.65</td>
<td>45.4</td>
<td>15.4</td>
</tr>
<tr>
<td>PAF$_{\text{day}}$</td>
<td>0.007</td>
<td>5.23</td>
<td>5.9</td>
<td>1.3</td>
</tr>
<tr>
<td>PAF$_{\text{All}}$</td>
<td>0.019</td>
<td>4.17</td>
<td>11.7</td>
<td>6.6</td>
</tr>
<tr>
<td>PAF$_{\text{Vig}}$</td>
<td>0.076*</td>
<td>2.66</td>
<td>4.3</td>
<td>4.4</td>
</tr>
</tbody>
</table>

Table 1 compares study variables for stress categories and presents means values and standard deviations for the subjects by stress category.

* not significant
ROC analysis revealed that activity days, $\text{PAF}^{\text{All}}$ and $\text{PAF}^{\text{Vig}}$ were all predictive of low stress in this population (Table 2). Several cut-off thresholds were available for $\text{PAF}^{\text{All}}$ and $\text{PAF}^{\text{Vig}}$. A $\text{PAF}^{\text{Vig}}$ score of two has a sensitivity of 60.0% (95% CI 40.6% to 77.3%) and a specificity of 70.4% (95% CI 56.4% to 82.0%) to predict low stress. A $\text{PAF}^{\text{All}}$ score of eight has a sensitivity of 62.5% (95% CI 43.69% to 78.9%) and a specificity of 74.1% (95% CI 60.4% to 85.0%) to predict low stress.

Figure 2: Exercise frequency and stress.

The relationship between maximum oxygen consumption and $\text{PAF}^{\text{Vig}}$ is shown. Equation: Polynomial: Second Order ($Y = A + B \cdot X + C \cdot X^2$) Best-fit values ($A = 26.31$, $B = 10.03$, $C = -0.6552$) 95% Confidence intervals ($A$ 14.23 to 38.39, $B$ 5.646 to 14.41, $C$ -1.018 to -0.2927).

Table 2: ROC area under the curves for activities that are significant independent predictors of low stress.

<table>
<thead>
<tr>
<th>Test result variable(s)</th>
<th>Area</th>
<th>Significance</th>
<th>95% Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lower bound</td>
</tr>
<tr>
<td>$\text{PAF}^{\text{All}}$</td>
<td>0.689</td>
<td>0.004</td>
<td>0.573</td>
</tr>
<tr>
<td>$\text{PAF}^{\text{Vig}}$</td>
<td>0.702</td>
<td>0.002</td>
<td>0.588</td>
</tr>
<tr>
<td>Active days</td>
<td>0.673</td>
<td>0.009</td>
<td>0.558</td>
</tr>
</tbody>
</table>

Active days = number of days per week with a minimum of one session of physical activity.

Table 2 displays ROC area under the curve, significance and confidence intervals for activities that are significant independent predictors of low stress.
Discussion

We sought to examine if questions on PA type and frequency alone could be used to estimate CRF and stress. We modified a single question from a validated and reliable questionnaire, to match our local populations PA frequency and type preferences. We then examined this PAFT question in two local populations. Vigorous style PA as estimated by the novel PAF\textsubscript{Vig} from PAFT had a strong association ($R^2=0.71$, $p=0.001$) with VO\textsubscript{2Peak} determined by the WHO recommended method in the first population. PAF\textsubscript{Vig} was also the most significant predictor (ROC area 0.70, $p=0.002$) of low stress in the second population. ROC analysis identified that two vigorous PA sessions or eight moderate PA sessions per week can be recommended as thresholds to decrease the risk of stress in this and similar populations.

The strength of our study is that we used direct CPX which is the gold standard WHO approach to assessing CRF and allowed us direct measurement of VO\textsubscript{2Peak}.\textsuperscript{12} This is now considered the most valid vital sign for general health and function.\textsuperscript{3,10,11} The method is labour intensive and only 20 subjects were assessed which may be considered a limitation. Nevertheless, the use of CPX does give PAFT a measure of validity that is rare in PA questionnaire validation. PAF\textsubscript{Vig} agreement with VO\textsubscript{2Peak} ($R^2=0.71$) compared well ($R^2=0.25–0.70$) with existing PA questionnaires.\textsuperscript{13} Therefore, we suggest that it is not necessary to estimate PA intensity and duration as specific questions in order to predict PA health benefit. Additionally, we believe PAF\textsubscript{Vig} may offer less bias as a PA metric as it is established that PA duration and intensity from questionnaires is particularly prone to this error.\textsuperscript{14} Also, the controversies of minimum single PA bout durations\textsuperscript{16} and intensity\textsuperscript{20} are removed with PAF\textsubscript{Vig}. PAF\textsubscript{Vig} appears to offer potential as a useful and particularly simple prescription for PA.

Age, tertiary study, PA frequency and type were all factors associated with increased psychological stress in our study population. The perception of psychological stress is markedly higher in younger individuals and those undergoing tertiary study compared with other individuals in the studied population. Unfortunately, the size of this exploratory study did not allow separate analysis of these groups. However, we should note this is an important finding, as psychological stress encountered when young appears to impart an increased risk of chronic diseases of ageing.\textsuperscript{24} The younger subjects in this study may be at higher risk many physical diseases.\textsuperscript{6,25,26} A growing body of evidence\textsuperscript{27} demonstrates that stress is a major concern with higher education students. Strategies to reduce stress in younger individuals undertaking tertiary study would likely benefit long-term health outcomes.

Our study supports that regular PA participation decreases stress, which is similar to consensus.\textsuperscript{3,28} However, only approximately half of studies suggest that higher PA or higher CRF levels are associated with attenuated responses to psychosocial stress.\textsuperscript{28} As such, there is little consensus on which types of exercise have the strongest impact on psychological stress.\textsuperscript{5} We found that PAF\textsubscript{Vig} were associated with a more profound reduction in stress when compared with PAF\textsubscript{Ad}. Additionally, we found that the greater number of sessions per week that an individual performs PAF\textsubscript{Vig} activities is also associated with increased reductions in perceived stress. We suggest that a reduction in stress with increased PAF\textsubscript{Vig} may be directly related to increases in VO\textsubscript{2Peak}. It is interesting to speculate that the optimum dose of PA to reduce stress may in fact be the same dose that improves VO\textsubscript{2Peak}. This would support the growing consensus that VO\textsubscript{2Peak} is an important health variable.\textsuperscript{3,10,29} One limitation is that health benefits from PA are specific to the population studied,\textsuperscript{5} and to the health outcome being measured. Indeed, given that that the tertiary students compared to other subjects reported significantly greater stress (mean ± SD 20.7±5.6 vs 12.2±7.5) the levels of PA to reduce risk of stress may only be consistent with our specific population.

Our findings suggest that simple frequency PA information can be used to estimate both CRF and health. PA frequency recommendations appear simple when compared with the minimum 75 minutes of vigorous physical activity, or 150 minutes of moderate PA durations recommended by many official guidelines. We suggest that two vigorous PA style sessions per week with no bout duration limit may be a simple recommendation for improving CRF and health. For extra health benefit, this may be increased into the range of 5–8 vigorous PA sessions per week which appears to be associated with the highest VO\textsubscript{2Peak}. In our current study, we suggest future research should focus on the relationships between PA frequency and all five components of physical fitness for health. If this valid, easy-to-use, rapid assessment of PA can be used with a wide range of patient populations, it may benefit many health professionals and their patients.
COMPETING INTERESTS
Nil.

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