Original Research Article

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Exploring the impact of short-term adherence to physical activity guidelines to improve the intrinsic capacity of older adults

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Abstract

Objectives: Cardiorespiratory fitness (CRF) and skeletal muscle mass (SMM) are both key parameters of intrinsic capacity. To date, the impact of adherence to physical activity guidelines by older adults on these facets is poorly understood. Therefore, this study aimed to assess the impact of 4 weeks adherence to UK physical activity guidelines on parameters of intrinsic capacity in older adults, with a secondary aim to determine the utility of a bedside-suitable predictive model of assessing CRF for predicting change in this parameter.

Methods: 14 older adults (22 % female, age: 66–80 years) completed a 4-week intervention in which they adhered to UK physical activity guidelines via a combination of supervised and home-based exercise. In addition to assessments of CRF via cardiopulmonary exercise testing and SMM via ultrasonography, whole-body and handgrip strength (HGS) and step-box test (SBT) variables were also measured before and after the intervention.

Results: Our intervention resulted in significant increases in CRF (ventilatory threshold (VT): +2.7 ± 0.9 mL/kg/min, $p<0.01$), vastus lateralis muscle thickness (+9 %, $p=0.02$) and whole-body strength (+47 %, $p<0.01$). There was no change in HGS or SBT performance. The bedside-suitable predictive model of CRF was not able to determine change ($R^2=0.11$, $p=0.25$).

Conclusions: Adherence to UK physical activity guidelines for just 4 weeks improves the CRF, SMM and whole-body strength of community-dwelling older adults. Collectively, these findings illustrate that adherence to current guidelines can improve key aspects of intrinsic capacity in older individuals. The impact of such interventions in populations at risk of accelerated physiological decline, warrant further investigation.

Keywords: ageing; exercise; strength; fitness; muscle; resilience

Introduction

Sarcopenia, the age-associated loss of skeletal muscle mass (SMM) and function [1] is independently linked with premature mortality, frailty, increased length of (hospital) stay (LoS) after treatment, and major postoperative complications [2]. Further, despite low SMM being an independent risk factor for poor clinical and pre-clinical outcomes, it has also been shown across the life-course [3], and in numerous clinical cohorts (e.g., cancer [4] patients) to have a strong relationship with cardiorespiratory fitness (CRF). CRF has also been shown as an independent entity to be predictive of all-cause mortality, morbidity and poor clinical outcomes [5]; with a particular wealth of evidence for the relationship between low CRF and poor surgical outcomes [6]. Taken together, SMM and function, and CRF are all important parameters for determining the intrinsic capacity of older adults *per se,* and as such older clinical cohorts.

In response to the ageing population across the globe, the World Health Organisation (WHO) has proposed that healthy ageing is “the process of developing and maintaining the functional ability required for a healthy life” [7]. Further, considering intrinsic capacity as the sum of an individual’s

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physical and mental abilities, the WHO have proposed *Guidelines on Integrated Care for Older People (ICOPE; 2024)* for the maintenance of intrinsic capacity [8]. Importantly, evidence from clinical trials shows that focussing on the intrinsic capacity of older adults is more beneficial than focussing on specific chronic diseases [9].

Recognising the importance of physical activity for the optimisation and maintenance of whole-body health, national and global (i.e., from the WHO) physical activity guidelines exist to inform individuals as to the ‘dose’ of physical activity needed to promote health and reduce the risk of chronic disease [8]. In the UK, these guidelines (2019; for adults over the age of 19) recommend: (i) strengthening activities that work all the major muscle groups on at least 2 days a week, (ii) at least 150 min of moderate intensity or 75 min of vigorous intensity activity each week spread evenly over 4–5 days a week, or every day, and (iii) reducing time spent sitting or lying down and breaking up long periods of not moving with some activity. There is also advice that physical activity recommendations can also be met via several short sessions of very vigorous intensity activity or a mix of moderate, vigorous and very vigorous intensity activity [10].

Although some efforts to tailor these guidelines for older adults have been made-for example, in the UK guidelines for older adults include “activities to increase balance and flexibility on at least 2 days a week to reduce the risk of falls” edits, these guidelines are often derived from experimental and/or epidemiological data in younger individuals [11]. Further, there are very few intervention studies assessing the impact of uptake and adherence to these guidelines by older adults, with those that do exist tending to focus on a single endpoint (i.e., either related to muscle *or* CRF), rather than multiple aspects pertaining to intrinsic capacity [12]. Indeed, the majority of studies that do explore the benefits of compliance with physical activity guidelines in older adults tend to be cross-sectional in nature, comparing those who are meeting the guidelines with those who do not [13], or based on biobank-type data [14]. In addition, across all age-groups, studies assessing the physiological impact of compliance with physical activity guidelines tend to explore intervention periods of 12 weeks or more [15], and although this is perhaps representative of behavioural change, it does not inform on the utility of adherence to these guidelines in time-limited situations pertinent to older adults such as, for example, surgical prehabilitation (i.e., for cancer, in the UK, the maximum time between to decision to treat and first treatment is 31-days [16]).

Considering CRF, an important aspect of intrinsic capacity which has utility in both clinical [17] (i.e., fitness for surgery) and research [18] (e.g., to determine intervention efficacy) settings, there are a number of challenges to its direct assessment via the “gold-standard” method of cardiopulmonary exercise testing (CPET). For example, CPET entails significant personnel and equipment demands, and is not feasible for those with physical limitations including, as examples, joint conditions and/or certain cardiovascular risk factors [19]; limitations which are more likely to present in older adults.

We have recently shown that simple to ascertain patient characteristics via bedside-suitable assessments of physical function are able to predict CRF [20]. As such, the main aim of this study was to assess the impact of 4 weeks adherence to (UK) government physical activity guidelines (via a combination of supervised and home-based exercise) on aspects pertaining to intrinsic capacity in older adults (namely skeletal muscle and cardiorespiratory function, and SMM), with a secondary aim to determine the ability of a previously developed bedside-suitable predictive model of CRF to determine change in this aspect of intrinsic capacity. The summary of this article is presented in Figure 1.

Materials and methods

Ethical approval

Ethical approval for this study was granted through the University of Nottingham Faculty of Medicine & Health Sciences Research Ethics Committee (16/EE/0137). All participants gave written informed consent to participate, and all research was conducted in accordance with the Declaration of Helsinki. This study was registered at clinicaltrials.gov (NCT06062784).

Participant recruitment

Independent, community-dwelling adults over the age of 65 years who were able to provide informed consent were recruited via local age-appropriate community groups. Interested participants were then invited to a screening session to assess their eligibility to participate against pre-determined exclusion criteria, including cardiovascular risk factors as outlined in the American Thoracic Society-American College of Chest Physicians statement on cardiopulmonary exercise testing [19]. Further exclusion criteria included uncontrolled hypertension, severe respiratory disease, known cerebral or aortic aneurysm, metabolic disease, disorders limiting a participant’s ability to complete any aspect of the study, or beta-blocker medication. Participants were not currently (nor had they been in the previous 24-months) engaged in any formal physical activity/exercise

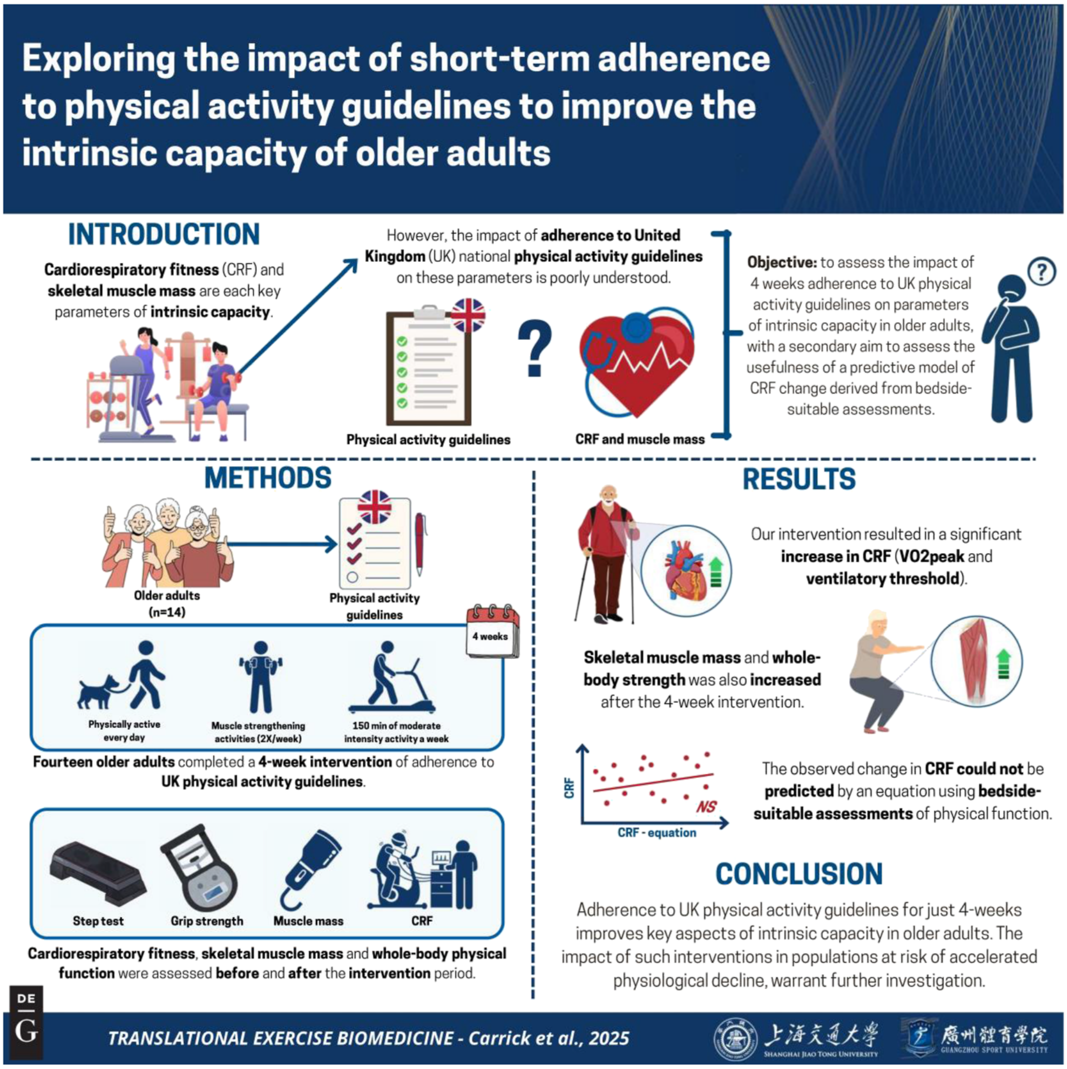

Figure 1: Graphical representation of this study. Key points: (1):(2) intrinsic capacity declines with advancing age. However, if short-term adherence to national physical activity guidelines for older adults can help mitigate this is not known. (2) Fourteen older adults completed a 4-week intervention involving adherence to UK physical activity guidelines. Aspects associated with intrinsic capacity, including cardiorespiratory and muscle function, and muscle size were assessed before and after the intervention. (3) Just 4 weeks adherence to physical activity guidelines improved multiple markers of intrinsic capacity. Promotion of this strategy could have marked benefits for older adults *per se*, and those at risk of accelerated physiological decline (i.e., those presenting for elective surgery). Figure created with BioRender.

regime, including adherence to the current UK physical activity guidelines, which was self-determined against the UK government physical activity guidelines infographic [21].

The sample size calculation was based on previous data from our laboratory [22] and assumed a minimum clinically important difference (MCID) in CRF of 1.5 mL/kg/min [17] (although this value has been argued to be as low as 1.0 mL/kg/min in certain older populations [23]). This was calculated using the pwr package in R. We aimed to achieve an 80 % power (1-β) with an α=0.05 and a standard deviation of 1.5. This determined a minimum of 10 participants would be required to determine changes in VT across our intervention period. We recruited more participants to allow for attrition based on experience conducting intervention studies in a similar population.

Assessment visits

Once eligibility was confirmed, each participant attended for their first assessment session whereby they had their height and weight assessed (to calculate body mass index (BMI)), completed three assessments of physical function (detailed below), and had the architecture of their vastus lateralis (VL) muscle assessed by B-mode ultrasonography (US). All assessment visits were conducted in the order outlined below.

Muscle ultrasound

VL muscle architecture, including muscle thickness, pennation angle and fascicle length, was assessed using the methods described by Franchi et al. [24] on the self-determined dominant leg. In brief, VL muscle architecture was assessed using B-mode ultrasonography (Mylab 70, Esaote Biomedica) with a 10–15 mHz, 100 mm, linear array probe (Esaote Biomedica). Three images were collected, and each architecture parameter assessed using imageJ software (National Institutes of Health, Maryland, USA) as previously described [24].

Physical function assessment 1 – step-box test

After US, the first physical function assessment, the step-box test (SBT), was conducted. The protocol for this was based on a multi-stage SBT specifically designed to predict aerobic fitness in older adults [25]. The step box test was conducted on a commercially available exercise step at a height (15, 20 or 25 cm) chosen by the participants as comfortable during a brief practice period. Prior to commencing the SBT, participant's resting heart rate (HR) was recorded (Mindray iMEC8). Participants were then asked to step at what they determined to be a "slow" pace for 20 steps as familiarisation. After 5 min rest, participants performed 20 steps at their "normal" pace, with time taken to complete this and maximum HR during this recorded. HR was also recorded after a 45-s recovery period (45HRR). Participants then rested for a minimum of 5 min or until their HR had returned to within 5 bpm of their resting value before performing 20 steps at a self-determined "fast" pace, with the same HR and time assessments (FST) as outlined above (Figure 2).

Physical function assessment 2 – handgrip strength

After a 10-min rest following the SBT, handgrip strength (HGS) was assessed using a handgrip dynamometer (Takei A 5401) as reported previously [26]. In brief, given the known impact of posture, arm positioning and verbal encouragement on HGS measures [27], all participants were seated in an armless chair with their shoulder in a neutral position and their elbow at 90°. Three readings of maximal HGS were taken for each hand, each a minute apart, alternating between dominant and non-dominant hand with the maximum for each hand recorded. Verbal encouragement was provided for each attempt.

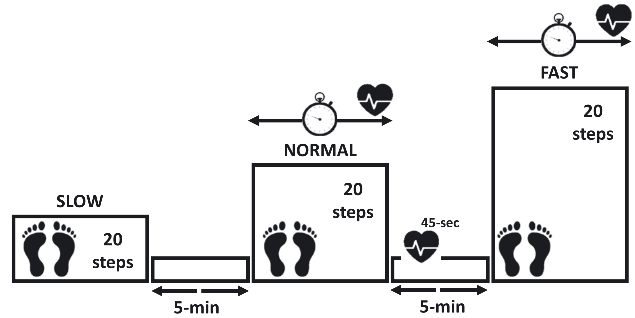

Figure 2: Schematic representation of the step box test protocol.

Physical function assessment 3 – cardiopulmonary exercise test

After resting for 10 min in a chair, participants completed a cardiopulmonary exercise test (CPET). Conducted using a cycle ergometer (Corival Cycle ergometer, Lode) with an inline breath-by-breath gas analysis system (ZAN 680, nSpire Health) connected to a face mask, a ramp slope protocol was used as reported previously [28]. In brief, participants were instructed to maintain a cycling cadence of 50–60 revolutions per minute (rpm) until the point of volitional exhaustion, which was defined as an inability to maintain cycling cadence despite verbal encouragement to do so and a score of >9 on a modified [1–10] Borg rating of perceived exertion scale (RPE) scale. Two experienced assessors independently analysed the data to determine CPET parameters of ventilatory threshold (VT; which was achieved by all participants) and VO_2 peak [29].

Physical activity intervention

After the initial assessment session, participants completed a 4-week intervention which involved adherence to the UK NHS guidelines on physical activity for older adults [10] before a repeat assessment. Specifically these guidelines state that adults aged over 65 years should: (i) be physically active every day, (ii) target activities which improve strength on 2 days per week, (iii) incorporate physical activity to improve balance and co-ordination on at least 2 days a week if they are at risk of falling, and (iv) aim to do at least 150 min of moderate intensity activity or 75 min of vigorous activity (or a combination of the two) each week.

As such, participants were required to undertake 150 min of moderate aerobic exercise training (AET) per week (in the form of cycling or brisk walking), and two sessions of supervised resistance exercise training (RET) engaging all the major muscle groups, as reported previously [30]. "Rest" days involved no formal exercise training, but activities of daily living (e.g., housework etc.) were encouraged in line with the recommendation that older adults should "be physically active every day". Supervised sessions took place in a research facility exercise training suite.

The 150 min of AET were divided into 5, 30-min sessions each of which could be split into shorter durations as per UK guidelines [10]. Three of the five sessions were fully supervised by the research team with the remaining two unsupervised and documented by self-report. The supervised sessions involved participants cycling at a wattage that was 50 % of the wattage at VO_2peak as determined from their baseline CPET. The two unsupervised sessions required participants to complete two 30-min (or a single 60-min) brisk walks or cycle sessions in >10-min episodes, across the week.

The RET involved three sets of 8–12 repetitions, with 90 s rest between each set of the same exercise. The exercises: (1) leg extension, (2) leg curl, (3) leg press, (4) lateral pull down, (5) chest press, (6) seated row, and (7) abdominal crunches are previously described [30]. To ensure participants trained at a sufficient intensity to elicit gains in muscle function and potentially muscle mass, the weight for each exercise was set at 70 % 1 repetition maximum (1-RM) (with the exception of abdominal crunches which were unweighted), which was determined at the start of the 4-week programme and then reassessed mid-way through to maintain training intensity with progression. For many participants (and likely reflective of the older adult population, especially those meeting our inclusion criteria of not adhering to current physical activity guidelines), using weights was a new experience and there was some anxiety around 1-RM assessments, despite familiarisation. As such, participants did not perform direct 1-RM assessments, but instead, this was calculated using the National Strength and Conditioning Association [31] training load chart based on the Landers equation of:

$$1-\text{RM} = (100 * \text{weight lifted})/(101.3 - (2.671 * \text{number of repetitions})$$

A log of attendance and compliance was recorded for each supervised exercise session with unsupervised sessions recorded by participants. Compliance with non-supervised sessions was >90 %. Participants would have been excluded had they failed to complete more than three consecutive supervised sessions, or more than six sessions in total across the intervention period. Of the 14 participants, two completed all 12 supervised training sessions, four completed 11 sessions, one completed 9, two completed 8, and two participants completed seven sessions. No participants were excluded.

Assessing change in CRF using accessible assessments

To explore the utility of the following equation:

$$\begin{aligned} VO_2\text{peak (mL/kg/ min)} &= 36.1 + (\text{non} - \text{dominant maximal HGS} \times 0.310) \\ &+ (\text{fast step box time} \times -0.156) + (\text{BMI} \times -0.66) \end{aligned}$$

which was previously shown to be moderately predictive of CRF (VO_2peak) [20], to determine *change* in CRF, we compared change in the equation-derived value for VO_2peak against change in the CPET-derived values for VO_2peak and VT. We also explored the relationship between post-intervention equation-derived VO_2peak and post-intervention CPET-derived VO_2peak and VT. Finally, we explored the relationship between change in independent measures from the assessment visits (muscle thickness, pennation angle, fascicle length, dominant and non-dominant HGS, FST and 45HRR) and CPET-derived change in VO_2peak and VT.

Statistical analysis

Statistical analyses were performed using Prism version 10.3.1 (GraphPad Software, LLC.), with all data reported as mean ± standard error of the mean (SEM), with significance set at $p<0.05$. Two-tailed paired Student's *t*-tests were used to compare before and after intervention values. To assess the ability of the previously reported [20] bedside-suitable model of CRF, or independent assessments to determine CPET-derived change in CRF, we used Pearsons's correlation. The same approach was used to compare the model-derived post-intervention value for VO_2peak with CPET-derived CRF values.

Results

Participants

Fourteen volunteers participated in the study (22 % female). The median age of participants was 72 years (range: 66 to 80). BMI was 24.1 ± 0.99 kg/m^2. No adverse events were reported for any part of the study (i.e., assessments or intervention).

Change in cardiorespiratory fitness

Both VO_2peak (VO_2peak: 21.73 ± 1.06 mL/kg/min vs. 24.59 ± 1.39 mL/kg/min, p<0.008) and VT (13.48 ± 0.90 mL/kg/min vs. 16.15 ± 1.25 mL/kg/min, p<0.008) increased across the intervention period (Figure 3). The magnitude of improvement was 2.86 ± 0.91 mL/kg/min for VO_2peak and 2.67 ± 0.85 mL/kg/min for VT.

Changes in muscle structure

Muscle thickness, but not pennation angle or fascicle length of the *m. vastus lateralis* increased across the intervention period (Table 1).

Change in muscle function

Change in muscle function was determined as a change in whole-body strength (an average across the six exercises (three upper-body and three lower-body) for which 1-RM assessments were conducted), HGS or SBT data (FST or 45HRR after fast-stepping).

There was an increase in whole-body strength across the intervention period (807 ± 154 N vs. 1193 ± 198 N, p<0.002) (Figure 4A), but no concomitant increase in HGS (for dominant: 27.4 ± 1.6 kg vs. 27.6 ± 1.7 kg, p=0.77, nor non-dominant: 24.8 ± 1.7 kg vs. 24.4 ± 1.9 kg, p=0.61) hands) (Figure 4B and C). There was also no improvement in either aspect of the SBT (FST: 31.2 ± 1.8 s vs. 30.5 ± 1.8 s, p=0.17, nor 45HRR after fast-stepping: 93 ± 2 bpm vs. 92 ± 3 bpm, p=0.45) across the intervention period (Figure 4D and E).

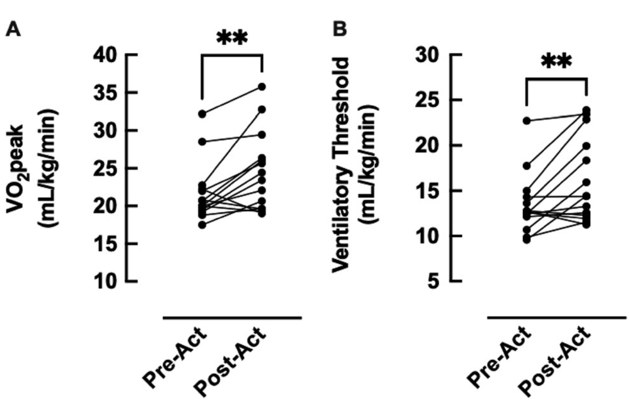

Figure 3: Cardiorespiratory fitness before (Pre-Act) and after (Post-Act) 4 weeks adherence to UK physical activity guidelines in older adults (n=14). (A) VO_2peak; (B) ventilatory threshold. Analysis via paired student's *t*-test. **=p<0.01 vs. pre-activity intervention (Pre-Act).

Table 1: Muscle structure before and after 4 weeks adherence to UK physical activity guidelines by older adults (n=14).

Parameter	Pre-activity	Post-activity	p-Value
Muscle thickness	1.94 ± 0.06	2.11 ± 0.08	0.02
Pennation angle	13.31 ± 0.53	13.31 ± 0.69	0.86
Fascicle length	7.55 ± 0.28	7.37 ± 0.23	0.52

Data shows mean ± SEM. Analysis via paired student's *t*-test.

Assessing change in CRF using accessible assessments

Upon exploring the utility of a previously reported bedside-suitable model [20] to determine change in CRF, we found that change in VO_2peak across our intervention period derived from the equation was not associated with CPET-derived (R^2=0.19, p=0.12). The same was found for VT (R^2=0.11, p=0.25) (Figure 5A and B, respectively).

The post-intervention CRF values derived from this equation were however associated with CPET-derived values for both VO_2peak (Figure 5C) (R^2=0.4, p=0.016) and VT (Figure 5D) ($R^2$0.32, p=0.035); displaying a similar predictive ability to that previously reported. No independent measure was able to predict CPET-derived change in VO_2peak or VT (Table 2).

Discussion

Our findings show that just 4 weeks adherence to UK physical activity guidelines, by independent community-dwelling older adults was able to improve their CRF, a key feature of intrinsic capacity. Importantly, the magnitude of CRF improvement was beyond that previously reported to be the MCID. Further, there was an increase in muscle thickness and whole-body muscle strength across the intervention period, illustrating the potential of uptake and short-term adherence to physical activity guidelines for improving the health and functional well-being of older adults. Finally, a previously reported predictive equation for the assessment of CRF using bedside-suitable assessments was not able to predict the observed change in CRF.

Exercise training has traditionally been divided into two broad types, each of which elicit distinct physiological adaptation. RET is primarily associated with improvements in muscle mass and strength, whilst AET is most commonly seen to improve CRF and aspects of metabolic health such as insulin sensitivity [32]. Given age-associated declines across multiple organ systems including, but not limited to those associated with skeletal muscle [33] and cardiorespiratory

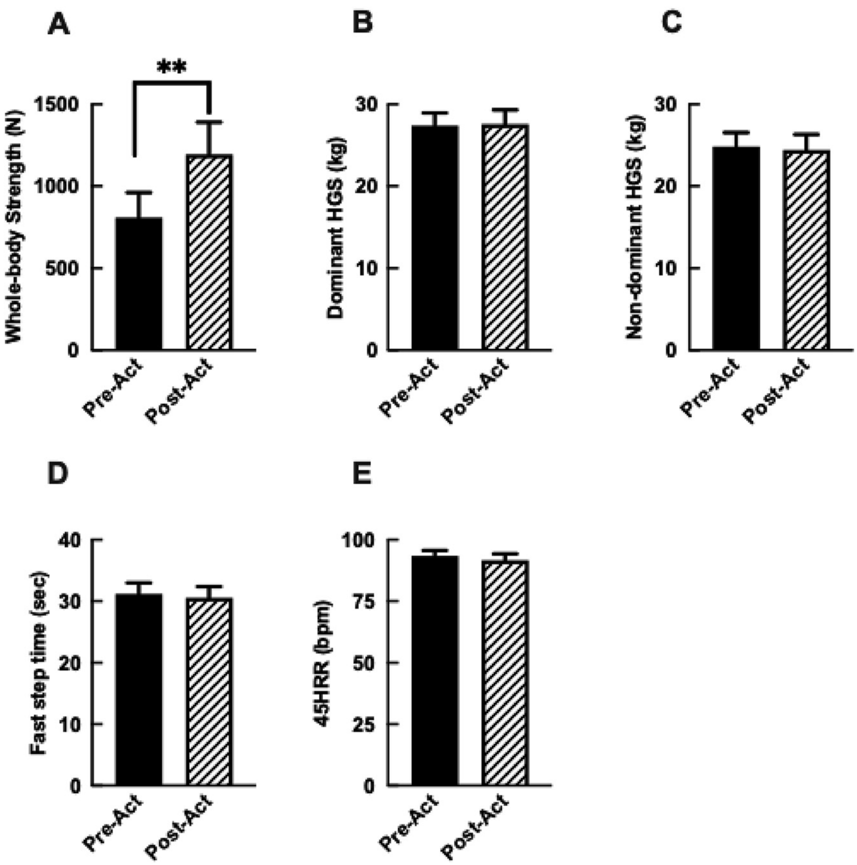

Figure 4: Muscle function before (Pre-Act) and after (Post-Act) 4 weeks adherence to UK physical activity guidelines in older adults (n=14). (A) Whole-body strength; (B) dominant handgrip strength (HGS); (C) non-dominant HGS; (D) fast step time: time taken to complete 20 steps on to a box at a self-determined "fast" pace; (E) heart rate recovery (in beats per minute (bpm)) 45-s after the fast-stepping phase of a step box test. Data shows mean ± SEM. Analysis via paired student's *t*-test. **=p<0.01 vs. pre-activity (Pre-Act).

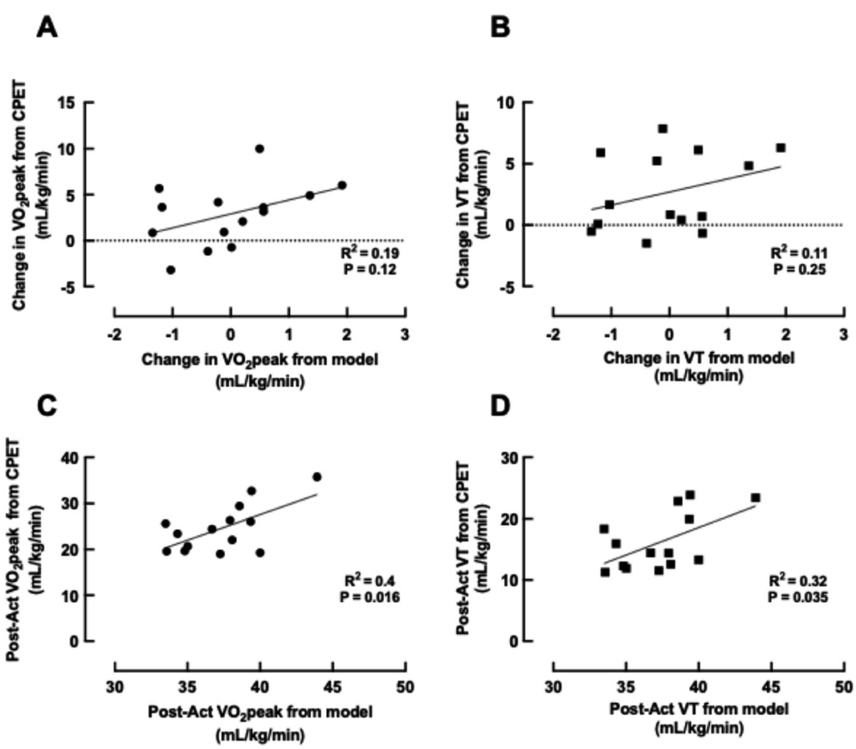

Figure 5: Linear regression analysis of change in (A) VO_2 peak and (B) ventilatory threshold (VT) from a previously reported bedside-suitable predictive model vs. cardiopulmonary exercise test (CPET) derived values after 4 weeks adherence to UK physical activity guidelines in older adults (n=14). Linear regression analysis of post-intervention (Post-Act) VO_2 peak (C) and VT (D) from this same model vs. CPET in the same cohort of older adults.

Table 2: Relationship between changes in CPET-derived CRF and changes in accessible physiological assessments after 4 weeks adherence to UK physical activity guidelines in older adults (n=14).

Parameter	VO_2peak mL/kg/min	VT mL/kg/min
Muscle thickness	R^2=0.13 P=0.23	R^2=0.16 P=0.18
Pennation angle	R^2=0.13 P=0.24	R^2=0.03 P=0.60
Fascicle length	R^2=0.17 P=0.16	R^2=0.009 P=0.76
Dominant HGS	R^2=0.006 P=0.78	R^2=0.009 P=0.74
Non-dominant HGS	R^2=0.11 P=0.24	R^2=0.19 P=0.12
Fast step time	R^2=0.005 P=0.80	R^2=0.02 P=0.65
45HRR	R^2=0.18 P=0.13	R^2=0.25 P=0.07

Analysis via Pearsons correlation. CPET, cardiopulmonary exercise test; CRF, cardiorespiratory fitness; VT, ventilatory threshold; HGS, handgrip strength; 45HRR, heart rate after 45-s recovery from 20 self-determined fast steps.

[34] structure and function, it is not surprising that both of these modes of exercise form the basis for physical activity guidelines for older adults across the globe [35].

The multiple cellular and therefore physiological function declines associated with advancing age combine to reduce the intrinsic capacity of older adults. Defined as “the sum of an individual’s physical and mental abilities” [8], reduced intrinsic capacity renders individuals unable to develop and maintain the functional ability required for healthy ageing [6]. Both CRF, and muscle mass and function are each associated with intrinsic capacity given their established contribution to optimal physical function, with, based on this, evidence to suggest that different forms of exercise training can improve the intrinsic capacity of older adults [22]. However, although there is a body of experimental evidence showing the positive impact of both RET and AET for improving key health-related aspects in older adults, (with comprehensive review articles available for each of these modalities [36, 37]) these modalities are relatively seldom studied in combination, and lesser still at the low frequency and intensity recommended by physical activity guidelines.

Given the paucity of studies exploring the impact of exercise that is represented in physical activity guidelines, it appears that the basis of these guidelines for older adults must have been extrapolated from studies performed in younger individuals [11]. Whilst these studies do offer insight into the physiological adaptation and associated health benefits that can be afforded by the type and degree of exercise forming the basis of these recommendations, they do not account for the differences in adaptive potential seen in older adults in response to both RET [38] and AET [39]. Herein, we report that uptake and adherence of UK physical activity guidelines can improve the CRF and muscle mass and function of older adults. Of note, the magnitude of improvement in CRF is above the previously reported MCID, and akin to that seen with the same duration of high-intensity interval training (HIIT) [40]; a modality of exercise which may not be deemed as accessible as moderate intensity exercise for certain cohorts of older adults.

Our observed improvement in muscle function [strength] is in agreement with other studies which have reported that RET at a similar intensity is able to elicit strength improvements in older adults, although again, the majority of these studies have employed longer intervention periods (e.g., [15]). Brook et al., did show that muscle strength improved with just 3 weeks RET in older adults, however based on the aim of this study (a mechanistic study focussed on muscle protein synthesis), participants only trained one leg and performed a much higher number of repetitions on a single exercise (leg extension – the exercise by which strength was assessed) than performed in this study [41].

The magnitude of whole-body strength gains seen in this study is higher than that reported by others who have also implemented an intervention in older adults. For example, Bell et al. reported a ~20 % increase in whole-body strength after 12 weeks exercise training comprising two RET sessions and one HIIT session [42]. This increase is approximately 50 % lower than the increase reported herein, yet similar to the findings of Betz et al., after 8 weeks RET performed by older males and females [43]. Although the RET component of the intervention of Bell et al. was almost identical to ours, this study was conducted only in males and although they did have an exclusion criterion of having participated in “any structured resistance or aerobic exercise training program in the previous 6 months”, there were no constraints on participants habitual physical activity levels. Further, all of the males studied by Bell et al., were able to complete direct 1-RM assessments. As such our relatively large increase in strength may be due to the low physical activity status (i.e., not meeting government guidelines) and confidence in physical ability (i.e., not comfortable performing 1-RM assessments) of the participants in this study, facilitating large potential to improve. Although response to exercise is not always negatively associated with baseline capability, a study by Kassiano et al., did show the greatest improvement in strength after a 12-week RET program in (at baseline) weaker compared to stronger older women [44].

A finding from this study which is not consistent with that of Phillips et al. who employed the exact same RET regime, albeit over 20 weeks, is the increase in muscle size (thickness) [30]. Although some studies have reported increases in muscle mass with RET by older adults, and hypertrophy has been suggested to predominate in the early phases of RET (i.e., 0–3 weeks [45]), other studies have demonstrated age-associated adaptive blunting in relation to RET-induced hypertrophy, often despite preserved functional gains [38]. A disparity in mass vs. functional gains is a common observation [38] and one which parallels age-associated declines whereby strength reductions are more rapid than mass [46]; suggested to be due alterations to neural components [33]. The results of this study suggest that older adults do have the adaptive potential to increase muscle size with only 4 weeks RET at the intensity recommended by physical activity guidelines (i.e., that required to increase strength).

Although SBT has been used in previous clinical studies as a measure of fitness [47] and HGS has been demonstrated across a number of studies to predict LoS, mortality, cognitive decline, and quality of life [48], herein we saw no increase in either of these measures of physical function despite an increase in CPET-derived CRF and 1-RM assessed muscle strength. This may be due, in part, to the fact that the volunteers in the present study were independent community-dwelling individuals, who were free from any significant comorbidities. Thus, it is feasible that assessments of physical function such as SBT and HGS may have lacked the measurement sensitivity and/or resolution to detect changes in CRF and strength.

A further aspect pertaining to physical activity guidelines that has not been well explored, and may have implications for older adults, is the temporality of adaptation to this form of exercise. To exemplify, as the population ages across the globe, the number of older adults presenting for surgery is increasing, and as such so is the interest in exercise prehabilitation [49]. However the opportunity for prehabilitation is often time-limited between diagnosis and treatment (i.e., <31-days in the UK for cancer surgery [16]). With improvements in CRF, and muscle mass and function often being key aims for prehabilitation based on their impact on anaesthetic risk and return to normal activities, our findings suggest that a recommendation to begin physical activity as per government guidelines, could improve the intrinsic capacity of older adults presenting for surgery in as little as 4 weeks.

Considering both older adults *per se*, and older surgical patients, accessible methods to assess CRF- the gold standard measure of whole-body physical fitness [50], could provide an opportunity to determine physiological status even in those who could perhaps not undertake CPET due to either physical and/or resource limitations. However, an equation using accessible methods of assessing physical function which was previously shown to be predictive of CPET-derived CRF, does not appear able to determine *change* in CRF and as such would not be able to assess the success of interventions aimed at improving this endpoint, or potentially declines over time/disease progression.

As with almost all research studies, there are limitations to consider. The absence of a control group is a significant limitation which means it is not possible to definitively state that some of the observed changes were not a consequence of participants being enrolled on a research trial. Participants were however instructed to maintain their normal habitual behaviour (i.e., diet and physical activity) as far as possible out with the intervention. However, it may be argued that if participation in the intervention elicited further positive behavioural change with regards to physical activity (i.e., walking instead of motorised transport or climbing stairs instead of taking the lift) this is an additional benefit of the intervention. Habitual physical activity (i.e., via accelerometery) was not assessed in this study and therefore the impact of this on our endpoints cannot be determined, nor can the definitive increase in physical activity performed; a limitation which should aim to be addressed in future studies.

Conclusions

We have demonstrated that just 4 weeks adherence to UK physical activity guidelines by older adults can improve multiple aspects associated with intrinsic capacity. Future work should aim to determine if this holds true in a more diverse group of older adults, including those facing known physiological challenges such as elective surgery.

Research ethics: Ethical approval for this study was granted through the University of Nottingham Faculty of Medicine & Health Sciences Research Ethics Committee (16/EE/0137).
Informed consent: All participants gave written informed consent to participate, and all research was conducted in accordance with the Declaration of Helsinki.
Author contributions: LC, JNL, JPW and BEP conceived and designed this study. LC, BD and AG carried out the experiments and analysis. LC, BD, PP and BEP wrote this manuscript. All authors gave their approval for this final version of the article to be published.
Use of Large Language Models, AI and Machine Learning Tools: None declared.
Conflict of interest: All authors declare that this research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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