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Physical Activity Promotion and Coaching to Support Healthy Ageing

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Abstract Physical activity plays a fundamental role in contrasting physiological deconditioning during ageing. Considering the complexity of the modifications that can occur in the physical activity domain, international guidelines recommend that older adults engage in a combination of aerobic, strength, flexibility, and balance training to promote active ageing and maintain adequate health status. For this reason, virtual coaches must be designed to prescribe appropriate physical activity plans in each of the specific target sub-domain. Technological solutions based on wearable devices and digital games are promising can be the key to a successful system. This chapter describes the physiological bases and the technological approaches implemented by the NESTORE system to evaluate users' functional abilities and to propose a comprehensive and individualised coaching plan in the physical activity domain according to the internationally recognised guidelines. The main technological NESTORE components, co-designed together with users to monitor their status and behaviour and coach them to perform effective physical activity, are (i) the NESTORE wristband that will assess the users' performances and monitor the main physiological parameters during aerobic activity and (ii) the NESTORE Pocket Odyssey mobile game that will engage the users during physical activities in the strength, flexibility and balance domains.

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1 Introduction

The benefits of regular physical exercise on health have been widely demonstrated in the scientific literature, whereas inadequate physical activity levels have been associated with about 10% of premature mortality [1–3], lower rates of all-cause mortality (e.g. coronary heart disease, high blood pressure, stroke, type 2 diabetes, cancer), as well as a higher level of cardiorespiratory and muscular fitness, healthier body mass and composition, and a biomarker profile that is more favourable for the prevention of cardiovascular disease, type 2 diabetes and the enhancement of bone health [4–6]. In addition, being physically active at ages over 65 has been associated with higher levels of functional health, a lower risk of falling, and better cognitive function, finally leading to a reduced risk of moderate and severe functional and role limitations in daily life activities [5].

Since deconditioning, low muscle tone, and/or low functional capacity contribute to poor health outcomes and low quality of life in older adults, the American College of Sports Medicine (ACSM) recommends that older adults engage in a combination of aerobic, resistance, flexibility, and balance training to promote and maintain health [7, 8]. The proposed physical activity guidelines suggest at least 150 min of moderate-intensity (increased breathing, able to talk) aerobic physical activity throughout the week or a minimum of 75 min of vigorous-intensity (breathing fast, difficulty talking) aerobic physical activity throughout the week or an equivalent combination of moderate- and vigorous-intensity exercise. These activities should be performed in bouts of at least 10 min of duration. Moreover, muscle-strengthening activities should be done involving major muscle groups, on 2 or more days a week. Older adults with poor mobility should also perform physical activity to enhance balance and prevent falls on 3 or more days per week [9]. In older adults, physical activity includes leisure-time physical activity, transportation (e.g. walking or cycling), occupational, household chores, play games, sports or planned exercise, in the context of daily, family and community activities [9].

In the last decades, the majority of the proposed strategies to match the current guidelines on physical activity and to promote a healthy lifestyle in older adults were resource-intensive, time-consuming and required costly interventions, especially in terms of human resources, factors that limited full participation and widespread dissemination [10]. It is therefore fundamental to develop effective and innovative solutions to spread a healthy culture among older adults.

2 Overview of NESTORE Coaching System in Physical Activity Domain

Modern society is flunked by technology which helps humans to perform several daily life activities. At these regards, wearable technologies can be innovative solutions for reducing sedentariness and, therefore, to increase adherence to current physical activity guidelines [11].

In this regard, NESTORE Coaching System wants to effectively and non-invasively act on the four main physical activity domains—aerobic, strength, flexibility and balance—by creating an individualized program based on continuous functional evaluations and user's needs. These four areas contribute to healthy ageing by maintaining functional capacity, strength, independence, and quality of life. In particular, the system is based on an initial evaluation of the users followed by an administration phase (see chapter "The Multi-domain Coaching Approach to Counteract Ageing Decline").

As part of the initial assessment, NESTORE Coaching System will ask the user to perform the modified-6-min Walking test (mod6MWT) and the modified-30-s Chair Rise test (mod30sCRT) to assess the user's aerobic fitness and lower limbs muscle strength, respectively. The mod6MWT is an adapted version of the clinical 6-min Walking test which is the simplest way to estimate the maximum oxygen consumption [12–14]. The mod6MWT measures the distance that the user can quickly walk on a flat, hard surface in 6 min. Subjects can choose their intensity of exercise and are allowed to stop and rest during the test. This test should be performed along a long, flat, straight, enclosed path with a hard surface that is seldom travelled [15, 16]. Based on the distance covered during the test, the user will be included in the "retain" group or the "improve" group. The mod30sCRT is administered using a folding chair without arms, with a standard height of about 43.2 cm, and which is placed against a wall to prevent it from moving. The participant is seated in the middle of the chair, back straight, feet approximately shoulder-width apart and placed on the floor at an angle slightly back from the knees. Arms are crossed at the wrists and held against the chest. The user should complete as many full stands as possible within 30 s and he is instructed to fully sit between each stand [17]. Depending on the number of stands completed the user will be assigned to the "retain" group or in the "improve" group. Thresholds for both tests are reported in Table 1.

As already highlighted in this book, the NESTORE coaching system wants to provide an individualized coach by meeting the user's needs. To optimize coaching prescription and avoid excessive engagement of the user, NESTORE will also take into account non-structured activities, defined as all the activities performed by the user which were not planned or included in the coaching programs. This comes from the need to create an active ageing model without being too intrusive in the user's life.

Table 1 Thresholds used in the mod6MWT and mod30sCRT. Accordingly, the user will be assigned to the "retain" group or the "improve" group

	Age	Man	Woman
mod6MWT	60–70	491 m	440 m
	70–80	400 m	350 m
mod30sCRT	65–69	12	12
	70–74	12	11
	75–79	11	10

3 Coaching Personalisation and Implementation Strategies

Exercise prescriptions designed for older adults should ideally include the four key components of exercise training (aerobic endurance training, strength/resistance training, flexibility, and balance) [18–21]. Although adjustments based on the user's goals and preferences are required, the focus remains on incorporating as many of the four components as possible into the exercise prescription. Many aerobic exercises, such as walking or running, can increase both endurance and strength to some degree. On the other hand, flexibility exercises require a separate prescription element: stretching exercises to enhance or maintain joint range of motion and to reduce pain. Finally, balance exercises challenge an older person's stability to improve his/her ability to avoid a fall when changing positions or negotiating uneven surfaces [22]. These four components of exercise training contribute to healthy ageing and the maintenance of functional capacity, strength, independence, and quality of life. Accordingly, coaching plans proposed by the NESTORE Coaching System covered these four intervention areas.

Cardiorespiratory function

Endurance training is crucial for improving the function of the heart, lungs, and vascular system, as well as for maintaining body weight and decreasing the risk for many chronic diseases [23]. In addition, older adults with increased cardiovascular fitness can perform more difficult physical tasks and exercise at higher intensities than those who do not undertake regular endurance activities.

NESTORE Virtual Coach will propose two alternative training pathways that will be identified accordingly to the status of the user previously assessed with the mod6MWT:

(a) Retain cardiorespiratory fitness. The coaching plans will be defined according to the general aerobic/endurance guidelines described above [4, 19].
(b) Improve cardiorespiratory fitness. The coaching plans will be based on the progressive increase of both duration and intensity, as tolerated by the subject, to achieve the exercise volume recommended by the guidelines [4, 19]. A typical example of a training program for a user in the improve group is shown in Fig. 1.

Interval conditioning will be the initial approach of choice because it is more flexible and produces rapid, specific aerobic endurance gains that positively influence the performance of daily activities. Moreover, interval training is timesaving compared to other types of programs.

After each training session NESTORE will ask the following parameters to the user:

- Recovery: using Total Quality of Recovery scale—12 h after the last session
- Fatigue: using Borg scale—following exercise cessation.

Moreover, the user will repeat the mod6MWT every 4 weeks to track changes in the user's cardiorespiratory fitness. Similarly, training adherence, fatigue and

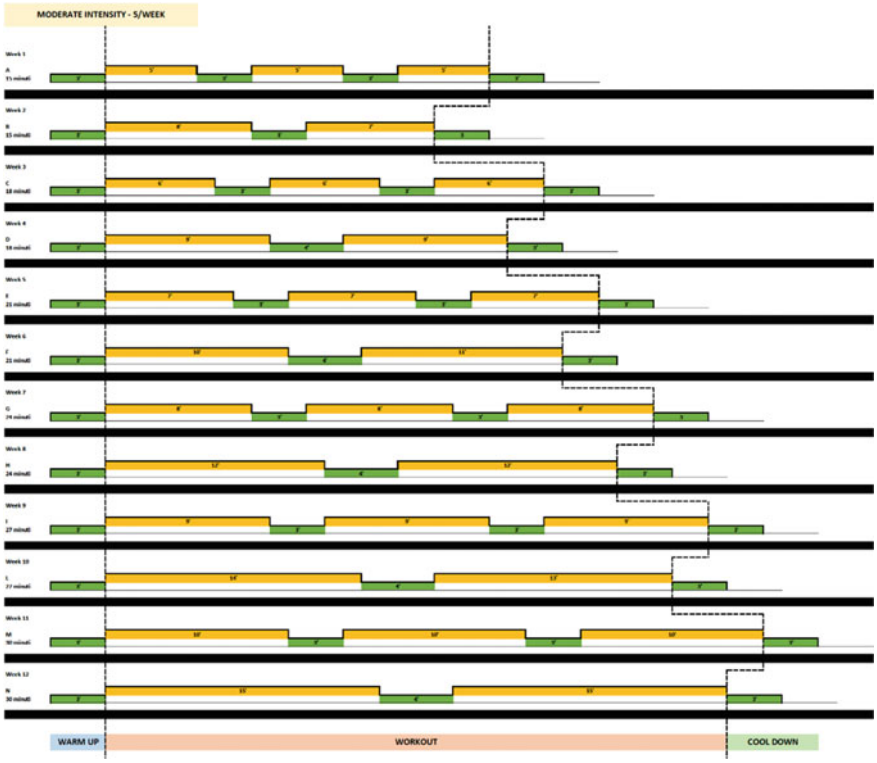

Fig. 1 A typical example of a coaching plan for a user who needs to improve his cardiorespiratory fitness. The intensity is light for the green bouts, while it is moderate for the orange bouts

recovery will be assessed too. Accordingly, the user will keep the same programme or he will be addressed to the other training pathways.

Strength

Older adults that regularly participate in a strength training program can improve muscle strength, function, bone density, and body composition as well as reduce their fall risk [24–26]. Strength training can also improve symptoms of many conditions: arthritis, osteoporosis, diabetes, and depression. ACSM recommends that older adults participate in strength training activities for at least 2 days per week [8], and the NESTORE system will follow these suggestions.

NESTORE Virtual Coach will propose two alternative target behaviours that will be identified accordingly to the status of the user assessed using the mod30sCRT:

(a) Retain muscle strength and power. The coaching plans for this target behaviour will be defined according to the general strength/resistance guidelines already reported previously in this chapter. In particular, the user will perform 3

sessions/week of moderate-intensity resistance exercises consisting of 3 sets each. Figure 2 shows a typical strength session for a user in the "retain" group.

(b) Improve muscle strength and power. The volume of exercise prescribed will begin at a low level and it will be increased as training continues. Moreover, as the load will be increased, so too should the length of the recovery period. The aim is to achieve the exercise volume as recommended by the guidelines. Progression may be individualized based on tolerance and preference in a conservative manner. In particular, each user included in this group will perform 3 sessions/week of light and moderate-intensity resistance exercises during the first 4 weeks and weeks 5–12, respectively. During weeks 1–4 of training, users will complete 5 sets for each exercise, while during weeks 5–12 they will complete 3 sets of 10 repetitions. Accordingly, repetitions and weights will be adjusted.

After each training session immediately following exercise cessation, NESTORE will ask the user his fatigue status using the Borg scale. Moreover, every 4 weeks

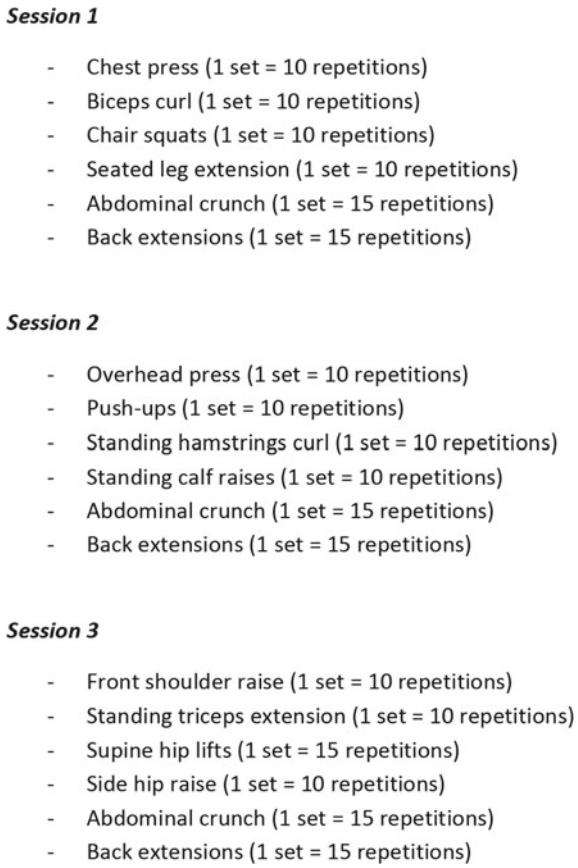

Fig. 2 A typical example of a coaching plan for a user included in the "retain" group in the strength subdomain. The intensity is maintained moderate throughout the 12 weeks of intervention

NESTORE will ask the user to repeat the mod30sCRT to monitor changes in the user's lower extremity muscle strength. Based on the fatigue status in the last 7 days and on the values obtained in the test, the user will keep the same programme or he will be addressed to the other training pathways.

Flexibility and Balance

Flexibility training allows older adults to maintain or improve their ability to perform activities of daily living such as combing hair, reaching for objects on a shelf or the floor, getting dressed, or putting on shoes. Flexibility training especially exercises focusing on the hip extensors, has also been shown to improve several gait parameters—speed, stride length, and cadence—which may result in increased mobility and reduced fall risk. In addition, stretching helps to prevent injuries, such as muscle strain, as well as reduces pain in the knee, hip, lower back, and neck.

Similarly, loss of balance and stability problems can lead to an increased risk of falls, fractures, injuries, and functional loss. Moreover, improvement in balance will not only reduce the risk of falls and injuries but may also increase the older adults' confidence in their ability to perform activities of daily living. Balance training usually consists of positions or movements that challenge the individual to maintain posture and stability over a base of support.

It is therefore fundamental to train and maintain these functions in older people. For this reason, NESTORE will provide a unique training program for both flexibility and balance to all the users, which should be performed twice a week. The system will create a single session by randomly choosing 9 different exercises for flexibility (4 for upper limbs, 3 for lower limbs and 2 for lower back/abdominals) and 4 exercises for balance.

Flexibility exercises should be performed after an aerobic session or before a strength session, while balance exercises should be performed after a strength session. The user should perform each exercise 2 times in a row (keeping the position for about 20 s each) with 20 s of recovery between.

4 NESTORE Technological Solutions for the Physical Activity Domain

Two main reasons have highlighted the need to develop technology strategies to help older people to live independently as long as possible: the continuous ageing of our society and the subsequent increasing pressure on health and aged care services.

To date, several technologies have shown promise as effective, accessible, and inexpensive solutions to promote health and wellbeing in global populations. In this regard, wearable devices were reported to significantly increase daily physical activity levels [27]. Similarly, video games were shown to positively affects both physical activity levels and cognitive function [28, 29].

This chapter section focuses on digital interventions enclosed in the NESTORE Coaching System aimed to increase physical activity levels in the target population. Concerning the entire system, here we particularly focus on systems that monitor user physical activity behaviour and provide a visual guide to exercises, to improve the health-related goals through a virtual coach.

Wristband

The user activities data shall be collected by dedicated devices, these devices are deeply described in the monitoring system chapter, nevertheless, this paragraph will provide an overview of the wearable wristband that is the main sensor used for physical activity.

The wearable device is similar to a smartwatch (Fig. 3) and it has been designed and developed following user-oriented guidelines like simple usage, not invasiveness and fast wearability. Mechanical dimensions are similar to a common watch (see Fig. 4) with a practical magnetic bracelet easy to be opened-closed and adjusted. A

Fig. 3 Wearable wristband. It is visible the user interface composed of a color LCD and a multifunction button, while a heart rate sensor is present on the back of the device

Fig. 4 Wearable wristband dimension and magnetic bracelet closure

color LCD display provides an easy user interface and a single multifunction button represents the main active user interface.

The wristband is equipped with sensors suitable to collect all the requested data about physical activities, in particular an accelerometer sensor that can detect walking base exercises and squats, while the combination with a barometer is used to refine the stairs count. The sensor present in the back of the wristband can measure also the heart rate of the user.

The purpose of the wristband is to collect data from the user and to transmit them to the cloud, passing to the app in the smartphone through a Bluetooth connection.

The physical structure involves different components like the smartphone app, the algorithm in the cloud that merges physical activities data with information coming from other sensors like the smart scale or nutrition, while a tangible interface is used for user feedback. In Fig. 5 the system architecture extract related to the wristband wearable is visible.

Once the user has connected the wristband to the app through a Bluetooth connection, the wristband starts to track standard activities performed by the user like walking steps, stairs and rest time that are analysed and processed by the algorithm to analyse sedentariness and daily activities of the user. In addition, upon app request, the wristband permits to start more a simplified/modified version of 30 s chair rise test and 6 min walking test, combining the measuring of the heart rate to the inertial sensors and transmitting the raw data to the app by Bluetooth, according to the synchronization protocol.

Even if the wristband is not designed to be a medical device, the sensors and the components used are based on the accuracy of the medical standard but the

Fig. 5 Wearable architecture connection

measurements are comparable to common healthcare devices for fitness usage, hence the combination of data gathered both from heart rate measurement and inertial sensors provides a good indication of the physical activity profile of the user.

Games

'Exergaming' describes the use of digital games or game elements to encourage people to do physical exercise [30]. While the physiological effects of exergaming are not considered better than traditional fitness, with exergames providing light-to-moderate physical exertion [31], exergames have shown players to be more interested and engaged compared to general fitness. For this reason, they are considered to be effective in making physical activity more approachable to inactive people [32]. Digital games, however, are often not necessarily accessible to everyone. When developing games to support older people in maintaining their well-being, it is essential to develop them in such a way that they are easy to understand, do not rely on specialized hardware, and are aligned with the preferences and interests of the audience [33, 34]. For this reason, the NESTORE game was developed with the requirements and wishes of older audiences in mind [35]. To lower the barrier of entry, the game is developed for mobile phones as our user studies showed this was a type of technology used by most older adults. However, while phones are accessible to many users, they also come with limitations. Sensor input (and therefore the ability to monitor a user's performance) is limited. Hence, the design described below focuses instead on providing users feedback during their workout and light game mechanics to engage them over a longer period.

Pocket Odyssey, the game developed as part of the NESTORE system, consists of three components. The first is the 'Ship', which functions as the main 'hub' for the player and allows access to the other parts of the game. The other parts are the 'Gym' and the 'Submarine' mini-games. The Submarine game is designed for cognitive training and as such will not be discussed further. The Gym game is an interactive visualization of the exercise routines outlined earlier in this chapter. The first time a NESTORE user starts the game, they are welcomed by the character Nestor. He is the player's guide to the game. In the introduction, he informs the player that he requires their help in fixing up his ship. Once Nestor has established the premise of the game, he guides the player through a short tutorial that explains the basic functionality.

The Gym game helps players in following pre-defined exercise routines. The character Nestor performs these routines on-screen through timed animations. Players select the type of exercise they want to do—strength, flexibility, or balance. Depending on the choice, players then either start exercising (balance or flexibility), or they select which routine they would like to perform (strength). After making this choice, the player is shown a screen with an explanation for the upcoming exercise. The structure of these screens is always the same—they show the two key positions of the exercise, as well as a textual description of the movement to be performed (Fig. 6).

The Nestor character performs the exercise on-screen with the correct timing. Repetitions are counted in the top-right corner. Motivational text is provided at the

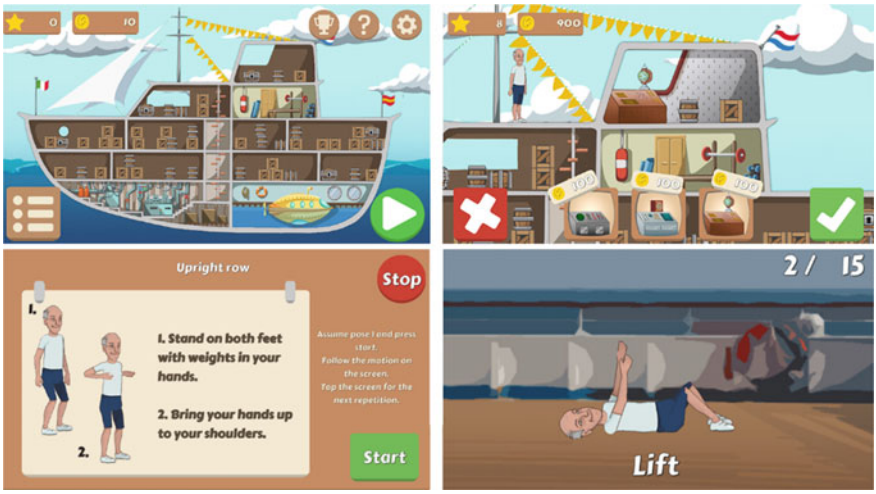

Fig. 6 Top: The initial ship (L) and customization options (R). Bottom: Example of an exercise explanation screen (L) and the Nestor character performing an exercise (R)

bottom to guide the player through the motions. If the player needs to perform the exercise on two sides (e.g., an exercise using a single arm), the game prompts the player to switch sides halfway through the repetitions. When the target amount of repetitions has been completed, the next exercise is explained. This process continues until the player has performed all exercises in the routine. At this point, the game checks whether the player has exercised enough for that day. If they have not, the player is prompted to continue with the next set. If they have, the game removes the option to continue and rewards the player. It is possible to finish a set, leave the game, and finish the required amount of sets later on. For flexibility and balance, there is no target to be reached. In these cases, routines only last for 1 set and provide a combination of movements.

Pocket Odyssey incorporates two types of reward, a feature adapted from existing mobile games such as Candy Crush Saga [36] or Homescapes [37]. The benefit of having multiple types of reward is the ability to pace the reward received by the player. The game aims to encourage players not just to play the game, but to play it the right amount (e.g., complete a physical exercise routine). A less valuable reward (coins) is used to reward basic interaction, while a rarer reward (stars) is used to reward commitment to achieving daily or weekly goals. These types of 'currency' can be used to fix up and decorate Nestor's ship to the user's taste. In doing so, the game provides an incentive to keep up with exercise regularly. While the content for the game is currently limited (i.e., users could 'finish' fixing up the ship), it could be expanded on to prolong engagement over a longer period.

5 Conclusions

This chapter summarized the physiological bases and technological approach utilized by the NESTORE Coaching System to evaluate older adults' functional abilities and to create individualized coaching plans in the physical activity domain according to internationally recognized guidelines.

The recent increase in sedentary behaviour, and therefore the prevalence of the associated disease, has pointed out the need to develop solutions aimed to increase physical activity levels in the general population. In particular, strategies are requested for specific age groups, such as older adults aged over 65, where it is fundamental to improve the quality of life associated with ageing. Among previous action programs, technological solutions have been proven to be effective in improving activity levels, also in the elderly. In this contest, NESTORE Coaching System wants to non-invasively and multidimensionally impact user's daily life physical habits by suggesting structured training sessions in the following subdomain: aerobic, strength, flexibility and balance. NESTORE final goal aims to bring the user to match the existing guidelines on physical activity by performing both daily non-structured tasks and structured activities.

References

1. Vidoni, E. D., Honea, R. A., Billinger, S. A., et al. (2012). Cardiorespiratory fitness is associated with atrophy in Alzheimer's and aging over 2 years. *Neurobiology of Aging*. https://doi.org/10.1016/j.neurobiolaging.2011.03.016.
2. Steell, L., Ho, F. K., Sillars, A., et al. (2019). Dose-response associations of cardiorespiratory fitness with all-cause mortality and incidence and mortality of cancer and cardiovascular and respiratory diseases: The UK Biobank cohort study. *British Journal of Sports Medicine*. https://doi.org/10.1136/bjsports-2018-099093.
3. Slemenda, C., Heilman, D. K., Brandt, K. D., et al. (1998). Reduced quadriceps strength relative to body weight: A risk factor for knee osteoarthritis in women? *Arthritis and Rheumatism*. https://doi.org/10.1002/1529-0131(199811)41:11%3c1951:AID-ART9%3e3.0.CO;2-9.
4. Physical Activity Guidelines Advisory Committee. (2008). *Physical activity guidelines advisory committee report*. Washington, DC US 67, 683. https://doi.org/10.1111/j.1753-4887.2008.00136.x.
5. Paterson, D. H., & Warburton, D. E. R. (2010). Physical activity and functional limitations in older adults: A systematic review related to Canada's physical activity guidelines. *International Journal of Behavioral Nutrition and Physical Activity*.
6. Paterson, D. H., Jones, G. R., & Rice, C. L. (2007). Ageing and physical activity: Evidence to develop exercise recommendations for older adults. *Applied Physiology, Nutrition, and Metabolism*.
7. Chodzko-Zajko, W. J., Proctor, D. N., Fiatarone Singh, M. A., et al. (2009). Exercise and physical activity for older adults. *Medicine & Science in Sports & Exercise*.
8. Pescatello, L., Arena, R., Riebe, D., & Thompson, P. (2014). *ACSM's Guidelines for exercise testing and prescription* (9th ed.).
9. WHO. (2010). Global recommendations on physical activity for health. *Geneva: World Health Organization, 60*. https://doi.org/10.1080/11026480410034349.

10. Coughlin, S. S., & Stewart, J. (2016). Use of consumer wearable devices to promote physical activity: A review of health intervention studies. *Journal of Environmental Health Science*. https://doi.org/10.15436/2378-6841.16.1123.
11. Stephenson, A., McDonough, S. M., Murphy, M. H., et al. (2017). Using computer, mobile and wearable technology enhanced interventions to reduce sedentary behaviour: A systematic review and meta-analysis. *International Journal of Behavioral Nutrition and Physical Activity*. https://doi.org/10.1186/s12966-017-0561-4.
12. Kervio, G., Carre, F., & Ville, N. S. (2003). Reliability and intensity of the six-minute walk test in healthy elderly subjects. *Medicine and Science in Sports and Exercise, 35,* 169–174. https://doi.org/10.1097/00005768-200301000-00025.
13. American College of Sports Medicine. (2014). *ACSM guidelines for exercise testing and prescription.*
14. Crapo, R. O., Casaburi, R., Coates, A. L., et al. (2002). ATS statement: Guidelines for the six-minute walk test. *American Journal of Respiratory and Critical Care Medicine*.
15. Enright, P. L. (2003). The six-minute walk test. In *Respiratory care.*
16. American Thoracic Society. (2002). Committee on proficiency standards for clinical pulmonary function laboratories. ATS statement: Guidelines for the six-minute walk test. *American Journal of Respiratory and Critical Care Medicine*. https://doi.org/10.1021/jo01342a038.
17. Alcazar, J., Losa-Reyna, J., Rodriguez-Lopez, C., et al. (2018). The sit-to-stand muscle power test: An easy, inexpensive and portable procedure to assess muscle power in older people. *Experimental Gerontology*. https://doi.org/10.1016/j.exger.2018.08.006.
18. Cress, M. E., Buchner, D. M., Prohaska T., et al. (2005). Best practices for physical activity programs and behavior counseling in older adult populations. *Journal of Aging and Physical Activity*.
19. Nelson, M. E., Rejeski, W. J., Blair, S. N., et al. (2007). Physical activity and public health in older adults: Recommendation from the American College of Sports Medicine and the American Heart Association. *Medicine and Science in Sports and Exercise, 39,* 1423–1434. https://doi.org/10.1249/mss.0b013e3180616aa2.
20. Fiatarone, M. A., O'neill, E. F., Ryan, N. D., et al. (1994). Exercise training and nutritional supplementation for physical frailty in very elderly people. *New England Journal of Medicine*. https://doi.org/10.1056/NEJM199406233302501.
21. U.S. Department of Health and Human Services. (2008). *2008 physical activity guidelines for Americans.* http://www.health.gov/PAGuidelines.
22. Sullivan, G. M., & Pomidor, A. K. (2015). *Exercise for aging adults: A guide for practitioners.* Springer.
23. Paterson, D. H., & Stathokostas, L. (2001). Physical activity, fitness, and gender in relation to morbidity, survival, quality of life, and independence in older age. *Gender, Physical Activity, and Aging*.
24. Hagerman, F. C., Walsh, S. J., Staron, R. S., et al. (2000). Effects of high-intensity resistance training on untrained older men. I. Strength, cardiovascular, and metabolic responses. *The Journals of Gerontology Series A Biological Sciences and Medical Sciences*. https://doi.org/10.1093/gerona/55.7.B336.
25. Hunter, G. R., McCarthy, J. P., & Bamman, M. M. (2004). Effects of resistance training on older adults. *Sports Medicine*.
26. Lemmer, J. T., Hurlbut, D. E., Martel, G. F., et al. (2000). Age and gender responses to strength training and detraining. *Medicine and Science in Sports and Exercise*. https://doi.org/10.1097/00005768-200008000-00021.
27. Bravata, D. M., Smith-Spangler, C., Sundaram, V., et al. (2007). Using pedometers to increase physical activity and improve health: A systematic review. *JAMA*.
28. Similä, H., Merilahti, J., Ylikauppila, M., et al. (2013). Comparing two coaching systems for improving physical activity of older adults. In *XIII Mediterranean Conference on Medical and Biological Engineering and Computing* (pp. 1197–1200). Springer, Cham.
29. Hanke, S., Meinedo, H., Portugal, D., et al. (2015). CogniWin—A virtual assistance system for older adults at work. In *International Conference on Human Aspects of IT for the Aged Population* (pp. 257–268). Springer, Cham.

30. Oh, Y., & Yang, S. (2010). Defining exergames & exergaming. *Proceedings of Meaningful Play*, 1–17.
31. Peng, W., Crouse, J. C., & Lin, J.-H. (2013). Using active video games for physical activity promotion: A systematic review of the current state of research. *Health Education & Behavior, 40,* 171–192.
32. Lee, S., Kim, W., Park, T., & Peng, W. (2017). The psychological effects of playing exergames: A systematic review. *Cyberpsychology, Behavior, and Social Networking, 20,* 513–532.
33. Marston, H. R. (2013). Design recommendations for digital game design within an ageing society. *Educational Gerontology, 39,* 103–118.
34. Nap, H. H., De Kort, Y. A. W., & IJsselsteijn, W. A. (2009). Senior gamers: Preferences, motivations and needs. *Gerontechnology, 8*, 247–262.
35. Kniestedt, I., Lukosch, S., & Brazier, F. (2018). User-centered design of an online mobile game suite to affect well-being of older adults. In: *International Conference on Entertainment Computing* (pp. 355–361).
36. King. (2012). *Candy crush saga.* https://king.com/it/game/candycrush.
37. Playrix. (2017). *Homescapes.* https://www.playrix.com/homescapes/.