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Smart systems for rehabilitation and independence

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Abstract

Globally, there is an increase in populations of older individuals. This elderly demographic presents its own unique challenges to the development of urban and rural areas, including the implementation of a physical environment that promotes the maintenance of independence in the face of the increased morbidity and impairment. The development of digital technologies that are being increasingly adopted by older individuals, including formats such as mobile apps and cell-phones, offer tools for assisting independence and improving physical and mental health in this age group. These digital technologies create opportunities to address health issues in older persons through their incorporation within specially developed physical environments. Such integration would allow development of targeted, age-specific tools to address motivational barriers, information delivery and data collection, while providing a platform that could facilitate information transfer with healthcare personnel. The development of outdoor interactive landscapes complemented with E-Health (electronic health) platforms and applications could efficiently utilise the environment to provide progressive engagement for the maintenance of a healthier lifestyle for the elderly. This paper aims to contribute to the ongoing research into the prevention of health loss, the maintenance of independence, and downstream economic benefits to healthcare systems.

Our project involved the systematic evaluation of commercially available outdoor equipment for older persons in concert with the exploration of digital technologies that feedback on performance, can deliver eHealth connections, or can allow data collection within a conceptual framework of an interactive landscape. Our research identified design parameters for appropriate outdoor interactive landscapes that will enhance older persons' physical and mental resilience, independence and wellbeing, with findings indicating that existing equipment is not well suited to a sustainable fitness programme for the elderly. Evidence suggests a holistic, multidisciplinary approach is required to effectively address those age-specific social, physical and motivation issues that are common within older age-groups. Further research is required into intergenerational playground approaches and feedback systems supported by informative eHealth technology.

Keywords: elderly; digital technologies; playground equipment; eHealth; feedback systems

1. INTRODUCTION

Increasing life expectancy has significantly increased the ageing population worldwide, with the age-group of persons aged 65 or older expected to grow by approximately 1.5 billion in 2050. [1] While advancements in health and science have contributed towards longer life expectancy, non-communicable diseases are now expected to be the greatest problem in global health, surpassing infectious and parasitic diseases [1]. These chronic diseases, not only

affect the physical well-being of the individuals, they also place excessive demands on health care systems and put financial pressure on the community[2], with the World Health Organisation (WHO) suggesting economic losses of approximately US\$83 billion between 2006 and 2015 from heart disease, stroke and diabetes. [1]

Studies have proven that physical inactivity is linked to hypertension, coronary artery disease, osteoporosis and degenerative arthritis. [3] These diseases; make the ageing individuals more susceptible to falls, decrease the amount of activity in daily activities, impact upon the ability to walk and exercise and overall result in a significant deterioration in the quality of life. [4] Conclusive evidence suggests that physical inactivity is one of the more important causes of chronic diseases, with 3.2 million deaths each year related directly to insufficient physical activity. [5] Preventative measures are therefore vital to reduce the financial burden physical inactivity places on the health care system.[6]

Current research validates the advantages of outdoor space utilisation by older persons (references, lots of them). Benefits not only include increased participation of physical activity but also the potential for social interaction. The natural settings foster stress recovery, decreased antagonism, and a documented reduction in the development of neuropsychological illnesses, [7] with the experience of independence in outdoor public spaces known to provide physical and psychological benefits. [7, 8, 9, 10] As a consequence of this increased interest in outdoor exercise for older persons, there has been an increasing demand for outdoor exercise equipment. [11] Despite this increase in interest, there is limited published predesign research that addresses the essential need for the equipment to be designed with outdoor maintenance in mind, effectively target specific muscles and bodily systems, be age-appropriate for morbidity prevention and rehabilitation, and be installed in a safe and stimulating context. As senior playgrounds and adult outdoor exercise equipment has only recently gained international popularity, there are risks that the equipment may be not entirely fit-for-purpose.

Digital technologies such as eHealth are being increasingly adopted by older individuals. These technologies offer tools for assisting independence, improving physical and mental health, and providing a sense of empowerment through learning for this age group. However, currently, few technologies are physically imbedded into outdoor exercise equipment so as to provide useful feedback. There is currently a gap between exercise equipment and medical feedback that is insufficiently addressed through iPhone apps and other digital devices. The development of digital feedback systems which can provide meaningful medical information have yet to be developed. Such an integrated system would allow development of targeted, age-specific tools to address motivational barriers, information delivery and data collection, while providing a platform that could facilitate information transfer with healthcare personnel.

This paper explores the theme of outdoor interactive exercise in older persons, focusing on an examination of current equipment and 'smart' e-health technologies designed for older persons in an outdoor environment, with the purpose of identifying how equipment and e-health are currently delivered and integrated.

2. METHOD

First, we performed an audit of outdoor exercise equipment that was specifically targeted for use by older persons through a systematic analysis of globally available outdoor exercise equipment. Gathered data included the location of the major manufacturing companies, the available products. Other variables included an assessment of how the equipment was

intended to perform, the proposed muscle groups targeted, whether there were any feedback mechanisms, the equipment materiality, durability, and the maintenance required. In addition to the collection of individual equipment information, case study information showing how the equipment might be incorporated into a ‘playground’ or grouped in an exercise setting was evaluated.

Second, a survey was undertaken to identify embedded feedback mechanisms and links to eHealth that indicated that these systems were still in developmental stages. In the absence of constructed technologies, we focussed on a review of the literature with respect to external feedback system and eHealth technology development. We also searched available literature from health, the sciences and design to identify both the beneficial and detrimental sides of the digital technologies for elderly. Information on the availability of the equipment was gathered online (Figure 1), and targeted muscle groups were categorised into the following regions; forehand & hands, arms, shoulder, upper trunk, lower trunk, thigh and legs.

3. FINDINGS

The World Health Organisation (WHO) recommends that older persons should do 150 minutes of moderate-intensity aerobic per week, balance exercise at least 3 or more days a week and muscle strengthening exercise 2 or more days a week. There are also recommendations suggesting an increase in exercise intensity to vigorous-intensity, if possible. Elders with impairment or disabilities are advised to do as much as their abilities or conditions allow. [12] Rehabilitation is defined as “people with disabilities in a process aimed at enabling them to reach and maintain their optimal physical, sensory, intellectual, psychological and social functional levels.” [13] The main objective is to provide people with tools they need to recover their independence and self-determination. [13] and independence is often defined in medical and health industry as:

*The ability to carry out activities that support one’s own lifestyle
and to control the care given by others. [14]*

As physical activity levels progressively decrease as people age, the prevalence of physical inactivity peak among adults aged 65 or higher. [15] Elderly people are largely found in three main types of living environments: independent living (e.g.: private homes), assisted living and nursing homes. [16] Studies found that many older adults prefer to “age in place”, however, regardless of where they choose to inhabit, physical activity is imperative to maintain or recuperate their independence. As studies found that elders who move into assisted living or nursing homes, they are more susceptible to further chronic conditions as they are previously dependent on people to care. [16] Not only there have experienced to some form of disability or impairment, cognitive and physical limitation occurs as they age. [16] Thus, to engage elderly in maintaining long-term physical activity is vital to prevent functional disability to prevent elders from moving into assisted living or nursing homes.

As previous findings validated current outdoor exercise equipment can provide users with muscular strengthening and cardiovascular fitness. However, the statistics of ageing adults engaged in physical activity have an adherence rates 30% in older men, while 15% in women, who maintain a long-term engagement in activity. And within 6 months of exercise, 50% of participants dropped out before they are exposed to any health benefits of exercise. [17] Thus, the importance of participating in long-term physical activity is crucial to maintain physical and mental independence.

Equipment	Muscular benefits	How to use	Cardio-vascular/Balance/ Muscle Strengthening
 SE 05 Arm Rotation	Forearms & Hands, Arms, Shoulders	Place your hands on the hemispheres of the turntable and turn it in one direction at equal or opposite. To massage place the palm on a disk and turn it.	Muscle Strengthening
 SE 09 Double Airwalker	Arms, Shoulders, Thighs	Stand on the foot plates and hold fast onto the handles.	Cardiovascular Fitness, Muscle Strengthening
 SE 10 Airwalker System	Arms, Shoulders, Thighs	Stand on the foot plates and hold fast onto the handles. Move your legs backwards and forwards.	Cardiovascular Fitness, Muscle Strengthening
 SP 02 - Bike & Stepper	Arms, Thighs, Legs	Sit down on the seat, place your feet onto the pedals and your hands on the bar. Bike with consistent pace and at the same time turn the bar around its axis.	Cardiovascular Fitness, Muscle Strengthening
 SE 06 Balance Seat	Upper and Lower Trunk	Sit down on the seat and hold fast onto the handles. Swing in all directions	Balance
 SE 02 - Twister & Stepper	Lower Trunk and Thighs	Twister: Stand or sit upright on the twister plate and hold fast onto the bar. Twist your lower body alternating to the right and left. Keep your shoulders straight and still. Stepper: Stand upright on the foot plates and hold fast onto the bar. Walk on the spot	Cardiovascular Fitness, Balance

Figure 1: Examples of common outdoor exercise equipment (name source)

Studies highlighted self-efficacy the main barrier in elderly people. Self-efficacy is “individual’s belief in their ability to successfully perform a specific behaviour”. [17] The ability of oneself, is based on the “performance experience or mastery, vicarious or observational experience of others, verbal persuasion, and emotional and physiological states.” [17] For some individuals, personal efficacy deteriorates health as the perceived capability reduces physical activity that could be susceptible to falling in future. Self-regulatory management such as goal-setting, monitoring progress, and self-reinforcement may be useful to overcome this barrier. [17] Furthermore, as inactive elders prefer to receive exercise advice from their own physician or health profession.

Due to minimal research on the effectiveness of outdoor equipment for elderly cohort, the following research has evaluated the design parameters such as materiality, colour, layout of equipment, cultural-inspired designs and trainings for cardiovascular fitness, balance and muscle strengthening. A limitation in this method was many manufacturers did not disclose any medical and testing report on the suitability of equipment. Furthermore, the research will focus on emerging topic of smart systems, with two parts, one focusing on the current eHealth system, while the second part explores feedback systems relating to health. Through this, it identifies some of the essential design parameters for appropriate outdoor interactive landscapes with the purpose of enhancing older persons' physical and mental resilience, independence and well-being.

3.1 Design Parameters for Rehabilitation Equipment

3.1.1 Function

The equipment surveyed was primarily designed for strength building, both muscular and cardiovascular. Secondary benefits involve development of balance and flexibility. Most equipment designed for cardio fitness and strength was very similar to that which one would find in a typical gym (Figure 1). Much equipment has been designed with both a single focus on a particular muscle group but some is designed for multiple training(s) such as muscle-strengthening and balance as well as cardiovascular fitness. The majority of equipment are designed for muscle-strengthening, balance and cardiovascular fitness, however, very few provide long-term engaging to participate in physical activity. A common similarity across all equipment, is the lack of ability to control the pace or the intensity of exercise, since the equipment was designed for elders with disabilities whom are the least capable users of the cohort. [18] In addition, the idea of ‘one-size-fits-all’ technology does not address specific needs for multi-chronic disease limitations. [17] As WHO suggested, increasing the intensity of exercise brings additional health benefits, thus there is a need to provide progressive and engagement in equipment to effectively address physical and motivational issues. Another problem with adherence issues relates to perceived barriers such as, judgement of their own capability to be able to accomplish the given task.

3.1.2 Materiality

Findings on outdoor exercise equipment are mostly made of steel with only some exceptions such as Richter Spielgeräte, who use mainly larch wood in their equipment. Studies reviewing outdoor exercise equipment found that steel is uncomfortable to use for many elders. [18] Furthermore, studies suggest that elders favour wood material because of the appearance, thermal resistant qualities, [23] and the natural setting that could foster stress recovery, decreased antagonism and documented reduction in developing neuropsychological illnesses. [24]

3.1.3 Culture-centred

Through some findings on equipment, mostly are designed based on traditional exercise methods from the local culture. For example, hand movement of the Tai Chi wheels imitates the hand movements of the Tai Chi martial arts. While cross-walk equipment, is mimics traditional Nordic walk exercise to provide full body exercise in cardiovascular and muscle-strengthening. [18] Though they are beneficial, ethnically diverse people are often most in need of exercise are faced with unfamiliarity of standardised traditional methods. [20] Thus, there may be a need to re-examine on the possibility of integrating relevant cultural practice into landscape.

3.1.4 Clustered Layouts

Exercise equipment is commonly grouped to allow several individuals to exercise at one time and to allow for a progression of exercise. Two types of outdoor equipment groupings have been identified: the cluster, which is most commonly used for circuit style training; and the trail system, which typically incorporates a walking-based workout. [21] The two systems operate quite differently in terms of sociability.

The cluster format typically permits visual contact and interaction with others exercising. This allows the user to see how the equipment could be operated as well as providing validation that at least one other person deems the exercise useful. Studies have found that female (cultural group) seniors preferred to exercise in groups which they reported gave them more motivation, confidence and enjoyment [22, 23]. Furthermore, a study found that the inclusion of a trainer or supervisor, for introducing elderly to the equipment, increased confidence within participating seniors, increasing the efficacy of these therapeutic landscapes. [25, 26] Some designers, Lappset, Kotobuki, Xccent and GameTime for example, incorporated socialising aspects into their equipment thereby potentially increasing the motivation for ongoing use.

A trail system requires a more linear format, whereby participants move from one element to another interspersed with walking. This system is beneficial as it encourages the participant to complete the sequence of exercises. The trail offers a narrative through the potential pathway or journey. For introverts, the trail offers the participant a chance to reflect, connect with nature and find energy in their inner world of ideas, concepts and abstractions. It can offer the quiet needed to recharge their batteries and engage with more contemplative, or spiritual aspects of the outdoors. No research could be found that compared the effectiveness of the two types of systems.

3.1.5 Colour

The colour of the equipment is important to create first impressions to engage users to use the equipment. Studies found that colour is an important physical factor because it affects the formation of public spaces that brings more encouragement towards participating in the physical activity. [27] Furthermore, as people ages, the vision becomes weaker. The choice of colour can add visual texture and sculptural interest, as it impacts deeply towards how we felt than expressed. [28] In addition, colour could provide a sense of safety through contrasting colour on pavement and seating that could compromised the senior's depth of vision. [26]

3.2 Feedback systems and eHealth technologies

Technology is often defined as an “application of scientific knowledge resulting in artefacts that support the practical aims of human life.” [16] As digital technologies become increasingly mainstream, there will be an increase in the adoption by elderly adults. Many see

this as having great potential for overcoming participation barriers. One of the strengths of technology is its capacity to easily adapt. [29] With all current barriers in adherence towards physical activity, the following part of the discussion explores how feedback systems and eHealth technology could be utilised to address participation barriers in physical activity.

There are currently four types of technological feedback systems related to health maintenance; that operated by health care professionals, that which is operated by individuals for maintaining their own health and that which is embedded in existing equipment.

The first group of feedback technologies are commonly used by health professionals and typically monitor physiological functions such as body temperature, pulse rate, respiration rate and blood pressure. [30] These monitors analyse “physiologic capacity to perform normal everyday activities safely and independently without undue fatigue.” [30] While they are available to the general public, they are typically expensive and require training to use and understand. Are they only available to healthcare professionals? How have you categorised?

Individual health feedback systems range from the simple app for a mobile phone estimating the number of steps taken in a day to more elaborate systems specifically designed for specific diseases or conditions such as diabetes, or cancer. While these technology are more accessible to everyone, the most common feedback systems are fitness technologies that track ones heart rate, sleep patterns, diet, or calories burned. Emerging wearable sensors have diagnostic, as well as monitoring applications. Their current capabilities include physiological and biochemical sensing, as well as motion sensing [31, 32], the communication hardware and software to relay data to a remote center, and the data analysis techniques to extract clinically-relevant information. Recent advances in sensor technology, microelectronics, telecommunication, and data analysis techniques have enabled the development and deployment of wearable systems for patients' remote monitoring. However, there remains a lack of affordable and accessible informative feedback on balance and muscle-strengthening that can be easily accessed by the elderly.

The third feedback technology is embedded technology, The functions are similar to wearable technologies, however they provide more accurate readings for the specific type of physical activity that are fixed into the machine. The simplest of these involves an embedded heart rate monitor in the handle of a walking machine. One of the most complex is the Health-e-chair, where it measures blood pressure, measure basic vital signs such as blood pressure, temperature, heart rate, lung sounds, blood oxygen saturation, motion and reflex response time to detect how susceptible elders are to falling. [33].

Finally the fourth and newest type of feedback systems are those that link gaming to medical equipment so as to increase participation. There are different approaches being used to unite therapeutic rehabilitation and gaming. Virtual environments and virtual reality based games are one approach that is quite popular. Another approach taken by occupational therapists has been to integrate gaming into their therapy programs using Nintendo or Wii-based equipment. Another technique used in rehabilitation employs force-feedback (haptic) technology to assist and aid patients. A natural extension from haptics has been robotic rehabilitation with systems that can both assist and challenge users. [34]

One of the barriers with new technology is being able to deliver a digital platform simultaneously between multiple devices. Research indicates there is potential to improve the quality of communication between doctor-patient, however, there is large disconnect between exercise equipment to feedback technology. It is therefore necessary to improve usability between technologies and digital platforms, in order to improve the quality of diagnostic and personal record that is required to be practically useful.

BENEFITS	BARRIERS
<i>Access to care</i> – The ability to independently access healthcare from anywhere and at any time of the day. Thus, consultation is quicker, convenient to work around patient and more efficient.	<i>Financial incentives</i> – Financial feasibility. Health professions may receive lower payment for an electronic consultation than regular consultation.
<i>Patient-centredness</i> – This is beneficial to patients as it allows patients to have access to their own health data and the ability to choose when or where they want to access their healthcare. Furthermore, the patient feels a sense of empowerment as they learn more and able to make easier their own health decisions.	<i>Stakeholders support</i> – Health professions to nurses to patients quite often people have conflicting interests. They might be lack of support in eHealth technology, as health professions may not have agreed to use technology
<i>Quality of Care</i> – Can incorporating medical guidelines and quality standards from multiple health professions, thus more accessible information resulting to a more quality of care.	<i>Cultural, organisational and psychological factors</i> – Context should also be considered. The possibility of technology replacing human contact can be a problem,
<i>Equity</i> – This refers to more chances of patients to receive access to health care, hence removing “distance and stigmatisation”.	<i>Legal issues</i> – Online diagnostic decision could often inflict legal issues as the suggestion could be inaccurate
<i>Innovation</i> – eHealth as a catalyst for innovation in healthcare. The ability to change how healthcare can be delivered.	<i>Lack of standardisation</i> – Interoperability is low. Different standards makes it difficult across all technology to exchange information.
<i>New Possibilities</i> – As newer technologies are made, it allows a range of possibilities for healthcare, providing sustainable change to the healthcare.	<i>Evidence of (cost) effectiveness</i> – Lack of evidence can lower financial incentive.
<i>Effectiveness</i> – Using technology to improve traditional exercise interventions, eg: wearable technology to track a person’s movement.	<i>Motivation and ability to use technology barriers</i> – Users may not know how to integrate technology into their daily routines and health professions still do not want or are unable to use technology.
<i>Efficiency</i> – With the possibility of eHealth to achieve the same quality of care, technology could reduce the number of doctor’s visit, making visit more efficient.	<i>Low reach</i> – Lack of diversity, only implicit to a specific group of people.
	<i>Non-adherence</i> – Motivational barriers leads to user to stop using technology.
	<i>Low inter-usability</i> – Lack of communication between to technology platforms lessens the added-value of using more than one technology.

Figure 2: Benefits and Barriers of eHealth technology. [35, 36]

4. CONCLUSION

This paper has explored how outdoor interactive equipment and current e-health technology could combine to provide older persons with a platform for maintaining and improving health in outdoor settings. It has found that while there are many available products and older person's utilisation of outdoor interactive equipment is currently being promoted, there are not currently any robust platforms or products that successfully integrate e-health systems with outdoor interactive equipment. There are also issues with much of the current outdoor equipment which appears not fit-for-purpose for an older persons demographic. It identifies some of the essential design parameters for appropriate outdoor interactive landscapes with the purpose of enhancing older persons' physical and mental resilience, independence and wellbeing.

Much of the outdoor exercise equipment targeted at older persons shares a strong resemblance to the indoor gym equipment that has been designed specifically to build muscular strength, balance and cardiovascular fitness in younger demographics. The key difference between outdoor and indoor equipment is that comfort is more commonly stripped to make it suitable for the outdoor environment and the equipment construction materials are more durable to be suited for the outdoor environmental conditions [37]. Purpose designed equipment suitable for the elderly and those less than able in an outdoor environment is scarce. Comprehensive design guidelines may be necessary for outdoor exercise equipment to provide engaging and comfortable rehabilitation for elderly.

In addition to the physical suitability of the equipment, there are significant participation barriers that need to be adequately addressed so as to successfully engage elderly persons in ongoing physical exercise. Identified issues include an overall lack of engagement; insufficient energy, and time; the inability to know how to use the equipment as well as feelings of incapability due to old age. [37] Others physical barriers such as those that exist when recovering from injury or incapacity suggests a need for progressive adaptable elements. In addition, the individualist nature of the equipment and the lack of a social dimension involving the company of others or interactivity was common theme. This may indicate that while the equipment may be appropriate for the required training of balance, muscle strength and cardiovascular fitness, the equipment may be ill-suited for the mental and social disparities within the ageing population. Early evidence suggests emerging technologies could potentially be a solution to provide a form of feedback communication and progressive engagement to the users.

Many elderly people rely on the ability of health professionals to recommend appropriate exercise guidelines, however much of the potential health benefit is lost because health professions can offer unclear directions and older persons suffer from poor concentration, memory deficits and dementia. [17] With eHealth and feedback system technologies, studies reported improvement in adherence to ongoing equipment use and training programmes. Contrary to popular belief, other studies have found that technology can also increase social connectivity, improving an individual's sense of wellness as well as biological, psychological, social and health well-being. [38] In addition, technology can aid in the removal of barriers to physical activity by improving or strengthening communication between health professions and patients. There is therefore the potential to innovate technology to create progressive engagement to have a long-term adherence in physical activity.

The development of outdoor interactive landscapes complemented with E-Health (electronic health) platforms, technologies and applications could efficiently utilise the environment to provide progressive engagement for the maintenance of a healthier lifestyle

for the elderly. Personality and culture have shown to be important modifiers requiring a more sensitive approach for sustainable exercise and further research is required into public exercise interventions with an intergeneration approach. Through specific targeted at improving balance and improving cardiovascular fitness, outdoor landscapes provide an alternative platform for enhancing older persons' physical and mental resilience, independence and wellbeing.

Finally, ease of use and cost-effectiveness are major considerations for elderly people when considering the adoption of digital technologies. [39] Many older patients are prescribed medication, complicated diets, exercises and other self-care tasks. Multiple chronic conditions create difficulty for patients in keeping track, managing high amounts of information and tasks. [39] These issues point to a requirement for holistic solutions in order to effectively engage elderly people with multiple chronic conditions, particularly when considering exercise equipment in outdoor interactive landscapes, the prevention of health loss, and the maintenance of physical and psychological independence in older persons.

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