

CHAPTER 21

Applications of innovative biomedical technologies for healthy ageing: Strategies for improving patient care and reducing healthcare costs in elderly populations

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Introduction

The world is experiencing a revolution in longevity. Is it beneficial at every age, in particular in terms of quality of life and does it lead to improved socio-economic outcomes? How can the actual digital revolution contribute to Healthy Ageing? We want to address these questions since innovative solutions are available for rapid and wide ranging societal impacts.

Rapidly changing demographics

Life Expectancy in occidental countries has drastically changed. Statistics from the French institute INED (Institut National d'Études Démographiques) report a value of 25 years of age in the mid-18th century, to 85.3 years for women and 79.2 years for men in 2020, an over twofold increase!

Until the middle of the 20th century the main factor for increased life expectancy was decreased infant mortality. Infant mortality has practically no longer any influence today, given its very low level.

Since then, life expectancy at birth has increased by 3 months per year on average in France. This increase is mainly due the successes achieved in the fight against adult mortality. People aged in their 80 and 90s are currently the population group growing most rapidly. For example, in Canada the population aged 85 and older is one of the fastest growing age groups, with a 12% increase from 2016. Currently, 2.3% of the population is aged 85 and older [1]. The prevalence of seniors 75+ was 9% of the French population in 2017 [2]. Life expectancy began to decrease slightly, from 62.7 to 61.9 years between 2006 and 2010 for men, and from 64.6 to 63.5 years for women between 2008 and 2010.

After age 60+, 7% of the population is affected by heavy dependency, i.e., for the basic activities of daily life (walking, eating, washing, dressing, etc.). Then after age 65+, the probability of becoming dependent is more than 40% (INED, 2012) [3].

Since ageing is associated with the onset of frailty and chronic diseases, leading to physical and cognitive functional decline, reduced autonomy and, eventually, physical dependency, persons aged 65 years or more should start to be screened in order to detect and prevent frailty, thus allowing the community to anticipate the consequences of ageing rather than simply enduring them [4]. Indeed, preventing and detecting a state of fragility early in people aged 65 or over is essential to avoid/delay its very deleterious and costly consequences [5].

Escalating health expenditures for the elderly

If these added years are dominated by declines in physical and mental capacity, the implications for older people and for society are more negative.

Healthcare costs as a function of age

As shown in Fig 21.1, population ageing drives up the costs of healthcare with a sharp increase after 55 years of age, see Canadian Institute for Health Information (CIHI) graph [6]. There is an exponential growth of healthcare costs as a function of age. They reach a maximum for people aged in their 80 and 90s. In France as an example, the prevalence of seniors 80+ was 9.6% of the French population in 2020 [7] The annual cost of dependency borne by the French State, the departments, Social Security and the French National Solidarity Fund for Autonomy (CNSA) is nearly 25 billion euros/year. Across the Organisation for Economic Co-operation and Development (OECD) [8] on average, public spending on old-age and survivor pension payments (7.8% of GDP) and health (5.6% of GDP) are the largest areas of social spending.

In case of early retirees, the research, sponsored by the global Society of Actuaries [9] using data from the Healthcare Cost Institute (HCCI) in the USA, estimates that retiree healthcare costs will be \$146,400 for persons age 65 who live 20 more years, while individuals retiring at age 55 will need \$372,400 to cover their healthcare costs to age 85. Therefore, early retirement may provide the retiree with poorer health conditions.

Escalade des dépenses hospitalières après 60 ans d'âge

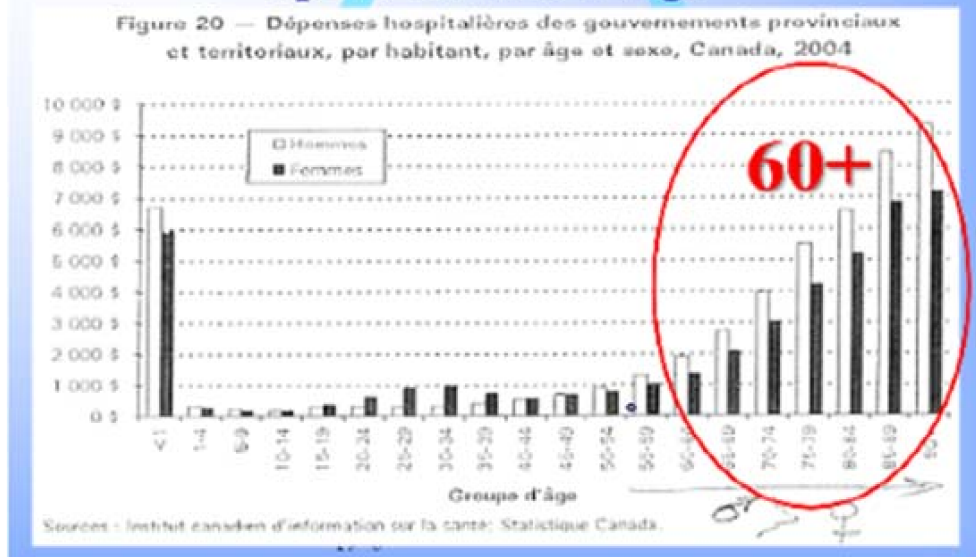


Figure 21.1 Canada 2004 hospital costs per age.

What is the economic value of supporting healthy ageing?

Andrew Scott [10] estimated the economic value of supporting healthy ageing: the estimated value of a 2.2-year increase in life expectancy for Americans 50+, is \$7.1 trillion, whereas the economic value of a slowdown in the rate of biological ageing that improves health and leads to a 1-year increase in healthy life expectancy is worth \$37 trillion.

Moreover, Dirk Broeders et al. [11] estimate: if the retirement age is fully linked to changes in life expectancy, welfare gains are substantially higher. In this case the riskbearing capacity of workers is particularly large because their labour supply acts as a hedge against macro-longevity risk.

In France, the prevention of dependency would make possible a saving of 10 billion euros/year in the long term [5].

Which factors play a role for healthy ageing?

The goal is to achieve healthy longevity by exploiting the malleability of age and ensure that life is not only longer, but also healthier and productive for longer. The potential of a longevity economy is the main focus.

Indeed, the above-mentioned calculations suggest that although providing services in later life is important, the most valuable products and services will be those that support healthy, productive, longer lives.

Medical care: A minor role for healthy longevity

There is a belief that medical care is the major factor for providing healthy ageing, and that it should benefit in priority from various allocations as compared to lifestyle investments.

However, in a 2019 review of four estimation methods, Kaplan et al. [12], conclude:

Molecular medicine tied with the ageing process

Biomedical research by Prof. Pierre-Marie Lledo [13] led to the discovery of two important biological mechanisms which are tied to the ageing process:

- One concerns the size of our protective telomeres. The more we live alone, the more our telomeres located at the ends of the chromosomes shorten.
- The second process is linked to the presence of particular cells, called senescent cells. Socially isolated people are those who accumulate the highest density of senescent cells, a density which becomes toxic for the organism because senescent cells secrete pro-inflammatory factors.

New paradigm for healthy ageing

Unequivocal conclusions were drawn by Prof. Pierre-Marie Lledo [13]:

“Our social life is the most determining protective factor for our longevity, much more than the practice of sport or a careful diet”.

The relationship with other people remains the only determinant capable of effectively combating the naturally occurring obsolescence of a subject.

It is therefore the lack of a social life which paves the way to frailty, increased medical care, and dependency, in a feedback loop which Prof. André Bonnin [14] called the “Wheel of Ageing” (Fig. 21.2).

Furthermore, Jennifer Molinsky [15] predicts if similar socio-economic conditions are being extrapolated:

The number of people living alone in their 80 and 90s is set to soar and reach 10.1 million by 2038 in the USA, and single-person households are more likely to report difficulties with self-care, independent living and mobility (Fig. 21.3).

Some response to this issue is led by the UN Decade of Healthy Ageing (2021—30) which seeks to reduce health inequities and improve the lives of older people, their families and communities through collective actions as listed below:

- changing how we think, feel and act towards age and ageism;
- developing communities in ways that foster the abilities of older people;
- delivering person-centred integrated care and primary health services responsive to older people;

- and providing, to older people who need it, with access to quality long-term-care

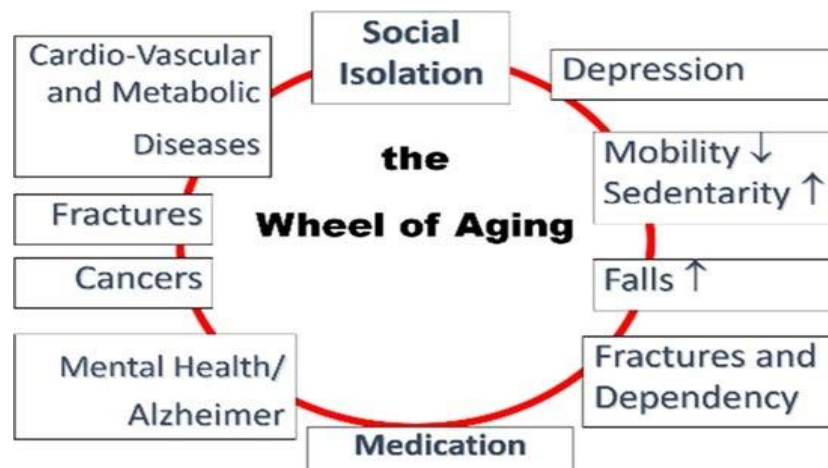


Figure 21.2 The wheel of ageing.

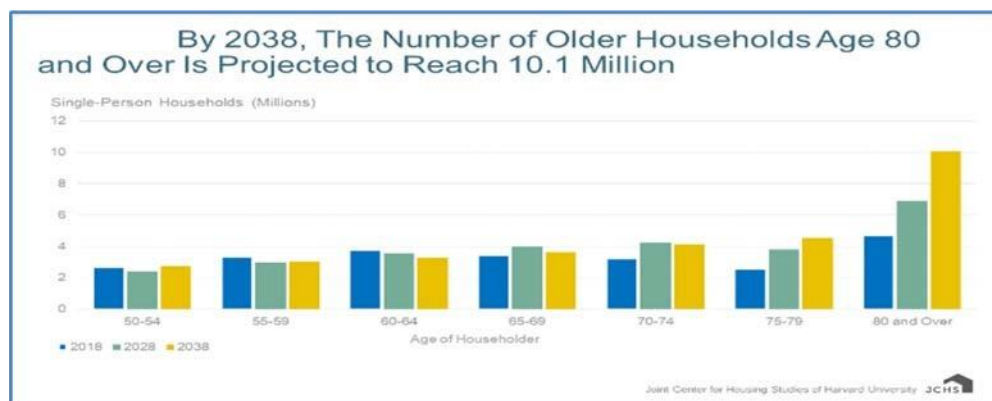


Figure 21.3 Ageing trends. (Harvard Joint Center for Housing Studies, *Housing America's Older Adults 2019*, www.jchs.harvard.edu. All rights reserved.)

Innovative technologies for healthy ageing

The purpose of the two following sections is to demonstrate that well-integrated technologies can bring positive impacts at low costs by allowing isolated people to interact with youth and health professionals, revive their link with communities, and even directly improve their health conditions, as measured in the following evaluations. Minor financial investments may in return allow major public health savings.

Already in 1994 it was important for the PACE2000 International Foundation to reduce the deleterious and costly consequences of isolation on the health of our populations, often confined in socio-professional, cultural and generational silos, particularly in nursing homes, and to contribute to the construction of an intergenerational structure beyond borders, for healthy ageing and societal peace [16].

Considering there are multiple barriers to the promotion of social relationships such as geographical, generational, ethnocultural and mobility restrictions, the PACE 2000 International Foundation has

Molecular Medicine and Biomedical Research in the Era of Precision Medicine

worked since 1994 at developing innovative, media, such as the design of Information Communication Technologies (ITC) to overcome these current barriers [17].

However, at the time, there were two main challenges:

- Would youth be interested in confiding in their senior telementor and exchange personal issues via videoconferencing in an organised programme?
- How effective can ITCs be in building relationships, particularly intergenerational links?

The Covid pandemic has widely popularised tele-work, however many applications made on the spur of the moment due to the urgency induced by the pandemic could be responsible for the following statement by Axelle Pignard, 2023: “Tools are at the service of man. These tools allow connection but not communion”. This belief is opposite to the general results of our evaluations over a decade of the operations of the Intergenerational Virtual Village [18,19].

Four phases of innovative development in co-design with users

Group sessions “The Intergenerational Bistro”

Using a videoconferencing codec applied to the local TV, sessions became accessible at home to isolated people, or in groups in long-term care centres in Canada and in the French *Établissement d’hébergement pour personnes âgées dépendantes* (EHPAD), in schools and colleges, preschool daycare centres and at the Catholic Immigration Centre in Ottawa, Ontario, Canada, for newly landed immigrants. The impacts of these “novel communities” were regularly assessed and provided rapid, diverse and unexpected positive outcomes.

Tele-physiotherapy and tele-evaluations of mobility

Further to the customisation of videoconferencing systems for the elderly and young, PACE 2000 added a means for the measurement of joints’ range of motion: The Automated Videoconference Based Goniometer (VCBG); (Patented in Canada and France) [20].



The VCBG allows the remote trainee to carry out automated measurements of persons in their distant homes in complete safety, from images already captured, assessed and saved by the clinician into individual files, followed, when needed, by subsequent checks from medical personnel.

The VCBG facilitates tele-monitoring and tele-rehabilitation at home from the hospital or the place of exercise of the health professional, after surgery or to motivate seniors to practice regular physical exercises [21]. Significant improvements in the range of motion of frail and homebound seniors have been assessed with the VCBG [22]. These goniometric telemetries also avoid trips to the hospital or clinic, where measurements are traditionally carried out manually using the Universal Goniometer.

Tele-geriatric evaluations

As reported [23], the videoconferencing assessment of autonomy, mobility, and nutrition were validated using the standard-of-care assessments of the French *Autonomie G rontologie Groupes Iso-Ressources* (AGGIR) agency, the Tinetti mobility test, and the *Association Qu b coise de d fense des Droits des personnes retrait es et pr retrait es* (AQRD), respectively, in a self-controlled randomized study (Fig. 21.4).

These results facilitate the early diagnosis of frailty and its long-term tele-monitoring.

Evaluation Scale	Respondent	Caregiver	Evaluation Scale	Respondent	Caregiver
Tinetti Balance Assessment	86.6	N/A	AGGIR: (IVc) Dressing and Undressing Mid Body	81.0	100
Tinetti Mobility and Gait Assessment	84.1	N/A	AGGIR: (IVd) Dressing and Undressing Lower Body	95.2	100

Figure 21.4 Sample of assessment table (10). Videoconferencing vs traditional assessment. (*Harvard Joint Center for Housing Studies, Housing America's Older Adults 2019, www.jchs.harvard.edu. All rights reserved.*)

The “4D” * intergenerational telementoring-teleconsultations

Continuing our journey of promoting an empathic relationship between a “trainer-trained” pair, one located at a distance from the other, we developed two other simultaneous VC dimensions for the Intergenerational Telementoring four dimensional “4D” (one: video, two: audio, three: interactive read, and four: write programme as illustrated below (Fig. 21.5) patented in Canada and France: its design implies bilateral, “trainer-trained”, sharing and editing of the same document in synchronicity, while observing and interacting with each other. This is to allow the trainer to be in front of his desk to share

and communicate in four dimensions with his “trainee” wherever the trainee may be. It also applies to collaborating live on the medical report of the patient during his teleconsultation.

For the Intergenerational Telementoring sessions, the appropriately matched “trainer-trained” pairs commit to 1-h weekly sessions for 7-10 weeks.

The impacts of this innovative technology, when appropriately designed, go far beyond those whilst in a physical encounter, which may limit mentors or health professionals.

4D = audio, video + interactive shared read and write.

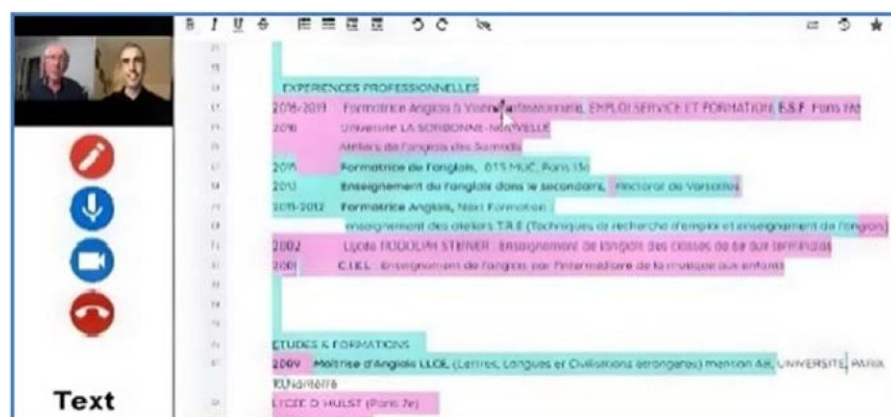


Figure 21.5 PACE-2-face 4D mode “Text Co-Edit.”

Far-ranging impacts with the use of innovative technologies

Soon after the initiation of intergenerational tele-mentoring programs, we were flooded with a wide variety of impacts reported enthusiastically by the users, young and “old-old seniors” which we could not have anticipated, since they could hardly be observed even after few physical encounters of young with seniors, such as in mentoring programs.

Testimonials

Before attempting at listing the diverse outcomes reported, let’s provide some testimonials and reported stories from participants:

Adele

Adele Thomas is a high school graduate, shy and uncertain about her future path. She joined the “Virtual Playschool” group and wrote:

Dear PACE 2000, I would like to thank you for the opportunities that you have given me. My volunteering for different sessions (of the “Virtual Playschool”) has been very enlightening. The sessions that I participated in with the children have made me realize that becoming a Developmental Services Worker is what I really want to do.

The children and the seniors seemed to have so much fun during the sessions. I am also amazed at the bond that was created between the telementor Evelyn Shore, the children and myself. I believe that children learn from communicating with others. The interaction teaches them skills that they will be using in the future.

My favorite part of participating in these sessions would have to be, when the shy children finally stood up and spoke to the person on the other side of the camera.

It took them a while, but to see them open up like that is what made my day. Seeing their faces light up when we made the connection always brought a smile to the faces of everyone involved. These sessions helped the children work on their self-confidence also. After a while, they were brave enough to dance in front of the camera (imagine 5-year-olds break-dancing for you).

When it was time to say goodbye to the children, I knew I was going to miss them, but they promised to drop by for a session every once in a while. I was glad to see that they also created a bond with me as I had created one with them. When you walk into a room filled with children and all of them run to giving you hugs, you feel like you've made a difference somehow.

Hopefully PACE 2000 continues to make this possible with others for years to come.
I would like to thank PACE 2000 for allowing me to participate in this programme.

Sincerely, Adele Thomas

Jill

Jill is a Co-op Student from Sir Robert Borden H.S., Ottawa. She joined PACE2000 as an IG coordinator and wrote:

Dear Dr. Bernard and PACE 2000,

Thank you so much for giving me the opportunity to work with your programme. During my cooperative education placement with PACE 2000, I learnt many things. The experiences I have gained over the past semester will stay with me throughout my life.

I am so grateful for the experiences I have gained which could not have occurred without all your help and direction. Working with PACE 2000 has changed the way I think about interactions with senior citizens.

I have a new strong appreciation for the seniors' many qualities, and the knowledge and experience they have to offer. Thank you for helping me along the path to my future!

Sincerely, Jill

Paul

Paul, an engineer from China, who served as an IG Coordinator wrote:

I am very happy with PACE 2000. The programme is very helpful for the Senior citizen. You may ask me what impressed me. Well, there always has been trust in me since I joined PACE 2000. I can feel the

trust from co-workers, the elderly, kids and teachers. I have learnt a lot about Canadian Culture and the way to communicate with the others in Canada from our Videoconferencing sessions. I have improved my communication skills in English a lot. Thank you for giving me such a friendly environment. I appreciate what you have done for me.

I will miss you and my friends of PACE 2000 wherever I am. Paul

General qualitative impacts

When using the above-described customised and intuitive videoconferencing means and telementoring programs, the list of feedback reported by seniors and youth is almost endless... and the outcomes appeared as unexpected blessings! Ongoing challenges consist mainly of keeping up-to-date with the rapid pace of technological changes which is an issue for all initiatives that employ ICTs.

When joining the Telementoring programme, Telementors need to be aware of their role as a partner, not as a teacher. Immediate behavioural changes are observed when each partner feels he is on an “equal footing”, shares games, images and stories. The table below lists 24 of the observed impacts.

<ul style="list-style-type: none"> • Quality of human relationships and promotion of empathy • Security and confidentiality • Rapid digital inclusion • Enjoyable learning conditions • Planning of meetings simplified • Expanded recruitments among seniors 60+ • New collaboration conditions “on an equal footing” • Breaking the isolation of seniors as well as of youth • Self-confidence and empowerment • Motivation for self-care • Freedom of speech and debates • Regression/disappearance of stereotypes • Ice-breaker in a context of absence of stigma • Rapid behavioural changes 	<ul style="list-style-type: none"> • New communication skills • Privileged and friendly bonds • Therapeutic telemonitoring optimization • International accessibility and wider crosscultural exchanges • Discovery of cultural differences between the English-speaking and French-speaking worlds on topical issues • First job acquisition facilitated and maintained • Communication and proficiency available from isolated seniors • Intergenerational mutual support • Bridges between communities working in silos • Vector of social, educational and professional inclusion
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Quantitative impacts

The impacts of each of these innovative tools had to be quantified during multiple evaluations, since their “custom made” design had yet to prove its efficacy!

Examples of results of published evaluation studies

Tele-Monitoring of the Mobility of Senior Citizens at Home after Orthopaedic Surgery by the Tele-Mentoring equipped with the VisioConference Based Goniometer VCBG [21].

The objective of the study was to evaluate the feasibility and user-friendliness of telerehabilitation and telemetry at home using the “Tele-Mentoring + VCBG” device with elderly patients, after orthopaedic surgery for total knee prosthesis.

The satisfaction index was 8.30 ± 1.62 for the Tele-Mentoring + VCBG device.

The quality of the tele-sessions was assessed $8,9 \pm 0,77$

Compliance to the 12 programed tele-sessions was 95.4% (103/108 scheduled for the month), without dropouts from the study; in addition, the automated recording of the dates and durations of the tele-sessions identified 17 additional tele-sessions carried out at the request of four patients.

These results allowed for a close telemonitoring of the patient’s conditions by the surgeon who, with the support of automatically plotted VCBG data, could detect early post operative complications and, when appropriate, request a visit to the hospital.

Tele-monitoring at home and intergenerational support: Feasibility and reliability of the evaluation of autonomy, mobility and nutrition by videoconference with seniors 70+ [23]

Randomized cross-over study, remote evaluations vs in situ measurements, of Tinetti mobility tests, the Nutrition Screening Initiative (NSI) in the USA and the French AGGIR scale (Fig. 21.6).

The statistical analysis looked for any discrepancy between the results of the teleassessment system and the face-to-face assessment, including with the universal goniometer.

Results:

- 21 people aged 82 ± 7.4 years completed the study.
- Cross-over intra-evaluator convergence (ICC) was excellent: $97.8\% \pm 2\%$ (Myers and Blesh scale).

These remote evaluations should facilitate an early diagnosis of frailty.

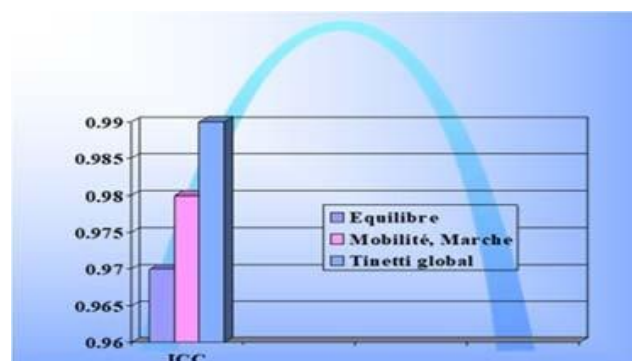


Figure 21.6 Tele-assessment versus face-2-face assessment.

Inter-Generational Tele-Mentoring for the Promotion of Social Relations and Health [18]

Marie-Madeleine Bernard, MD, PhD, Kamel Ouacel, Mathias Fruhwirth P.Eng, Martin Brooks, PhD, Kate Oakley, PhD, Xuemei Wang, PhD, Karim Guillaume Ouechni, B.A.Sc, Frederick Janson, MBA.

Telementors aged between 55 and 82 and young people aged 14 to 23, formed 18 inter-generational (IG) pairs and expressed averages rates over 80% of appreciation of their programme using the “4D” IG Tele-Mentoring tool: they were able to develop a particular interest in the human relationships, the feeling of complicity and communication “on an equal footing”, and the opportunity for personal development and intercultural exchange.

Video-conference based physiotherapy and tele-assessment for homebound older adults: A pilot study [22]

Seventeen home-bound older adults aged 75+ (mean 82.4 ± 7.2 yrs) participated in a 10-week exercise programme, up to a maximum of three sessions per week. All participants presented with at least one chronic disease. The most common chronic diseases were osteoarthritis, cardiovascular diseases, hemiplegia, Parkinson's, diabetes and early Alzheimer's (Advanced dementias were part of secondary exclusions). The previously validated Videoconference Goniometer was used to assess range of motion at baseline and after 10 weeks.

Results: Significant improvements were found in measures of strength and range of motion in these frail homebound older adults, aged 75+, at the end of the 10-week programme.

This study demonstrates the feasibility of delivering and monitoring telephysiotherapy as well as measuring unexpected mobility improvements in these home-bound frail/dependent older adults.

Conclusion: New strategies needed for healthy ageing

The new paradigm stressing the prime importance of social life for healthy ageing, implies governmental planning for early large scale preventive campaign strategies for “young seniors” 55+, assessing frailty and favouring social lifestyle and intergenerational teleactivities along with physical exercise and appropriate diets.

Medical care at these stages which include frailty, is of minor impact on healthy ageing. We have assessed that frailty and even early stages of dependency can still be reversed by social lifestyle changes. The escalating health costs occur at the stage of dependency, when the chances of longevity in good health have disappeared.

Considerable savings (3 trillion\$/year. for the USA) could be achieved by a shift of investments from curative to preventive measures.

In France, the prevention of dependency would make possible a saving of 10 billion euros/year [5].

The focus led by the United Nations, UN Decade of Healthy Ageing (2021—30), seeks to reduce health inequities and improve the lives of older people, their families and communities through collective actions. Those listed below can be achieved with the support of innovative technologies:

- changing how we think, feel and act towards age and ageism;
- developing communities in ways that foster the abilities of older people

Innovative solutions are required for the implementation of rapid changes, such as quality and customised videoconferencing technologies, vectors of appropriate programmes: customised “4D” technologies have proven their success and channelled an extraordinary flow of empathy, motivation, intergenerational support and rapid improvements towards healthy lifestyle activities for seniors.

The discovery of multiple impacts which go beyond the hindrances of face-to-face presences, should warrant rapid and large-scale distributions, providing longevity in good health in parallel with drastic economic savings.

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Conflict of interest

- Marie-Madeleine Bernard, Founder and Administrator of the PACE2000 International Foundation, Patent holder in Canada and France: “4D” Intergenerational Telementoring, and VideoConference Goniometer.
- Mathias Fruhwirth, PACE2000 Technical Director, Patent holder in Canada and France: “4D” Intergenerational Telementoring, and VideoConference Goniometer.

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