Received 29 July 2024
Revised 7 December 2024
13 January 2025
Accepted 26 January 2025

Taking a life-course and integrated approach to musculoskeletal and physical health in Singapore

Bryan Yijia Tan, Andrew Ian-Hong Phua, Ivy Wei Fang Ho, Aidan Lyanzhiang Tan, Shieh Yng Lian, Clive Tan, Chin Sim Teoh, Soon Yin Tjan, Yew Yoong Ding and Tock Han Lim
(Information about the authors can be found at the end of this article.)

Abstract

Purpose – Musculoskeletal conditions present a significant care and disability burden on our societies, and current approaches focusing on specific diseases or anatomical sites result in episodic, procedure-focused care. A novel framework that combines integrated care principles and a life-course approach is needed.

Design/methodology/approach – Through a combination of literature review and theoretical synthetic approach to current frameworks, an expert clinical workgroup synthesised and implemented a life-course and integrated framework and approach to musculoskeletal health.

Findings – The implemented framework (1) takes a life-course view of musculoskeletal and physical health, (2) shifts focus away from an anatomical to functional perspective, (3) encompasses activity and participation in addition to body structure/function, (4) demonstrates the associated mental and metabolic health issues and (5) highlights opportunities for primary, secondary and tertiary integrated interventions at different levels and care sites.

Originality/value – This life-course and integrated framework and approach can be applied to guide macro-meso-micro integrated care strategies, drive the research agenda and promote educational efforts for musculoskeletal and physical health.

Keywords Musculoskeletal health, Physical health, Life-course approach, Integrated care, Framework

Paper type Conceptual paper

Introduction

Musculoskeletal conditions are the leading global cause of years lived with disability (YLDs) (Nguyen *et al*., 2024) and the third-leading cause of disability-associated life years (DALYs) (Nguyen *et al*., 2024; Guan *et al*., 2023), associated with high costs (Chen *et al*., 2023) and comorbidities (Edwardson *et al*., 2012). Current care systems demonstrate fragmented delivery and evaluation, with a lack of system-wide models of care, monitoring and evaluation (Johansen *et al*., 2019). The prevalence and costs of musculoskeletal conditions and procedures are also rapidly rising, which may overwhelm already overburdened health systems (Joshipura and Gosselin, 2018). Integrated care models and solutions that promote person-centric, preventive and holistic health are urgently needed in musculoskeletal and physical health.

Historically, approaches to musculoskeletal health have been anatomical, symptom-centric, focusing on individual body parts (National Academies of Sciences *et al*., 2020).

Journal of Integrated Care
Vol. 33 No. 5, 2025
pp. 36-50
Emerald Publishing Limited
e-ISSN: 2042-8685
p-ISSN: 1476-9018
DOI 10.1108/JICA-07-2024-0041

Bryan Yijia Tan and Andrew Ian-Hong Phua contributed equally to this work and are designated as co-first authors for this work.

For instance, historical beliefs about osteoarthritis (OA) are that it was a normal part of ageing, related to "wear and tear", and joint replacement was inevitable (Jinks *et al*., 2023). Such rhetoric has resulted in episodic, isolated and procedure-focused care that does not address multi-dimensional causes or provide whole-of-person, continuous care, causing dissonance with the patient's experience (Bunzli *et al*., 2021). Such an approach causes many gaps, including silos of care built around body parts rather than individuals (Chehade *et al*., 2020), lack of communication between these services (Kobayashi *et al*., 2022) and inability to coordinate across the wider ecosystem (Chehade *et al*., 2020).

Musculoskeletal health can be seen as a part of the wider continuum of physical health (Clark and Ellis, 2014). The "physical" concept encompasses not only the range of musculoskeletal health such as strong muscles, strong bones and healthy joints but can also be affected by larger social determinants. For example, poor social support has been linked with worse pain (Nicolson *et al*., 2020) and musculoskeletal morbidity outcomes (Woods, 2005), and poor mental health has been linked with common musculoskeletal diseases (Heikkinen *et al*., 2019). There is increasing recognition of the importance of person-centred care including activity and participation, social determinants of health such as lifestyle, technology and even the built environment (Ball *et al*., 2015).

These concepts of whole-of-system design and person-centred health speak to integrated care, which for this paper we borrow World Health Organisation's (WHO) definition to define integration as helping expand the "continuum of health promotion, disease prevention, diagnosis, treatment, disease-management, rehabilitation and palliative care services" and further involve "the different levels and sites of care . . . throughout the life course" (World Health Organization, 2015). In viewing the ideal state of integrated health services, we recognise there is a gap in the area of physical and musculoskeletal health for a holistic conceptual model incorporating integrated care principles, and individuals' growth and progress through their whole life-course.

Singapore is an island city-state in Southeast Asia with close to 6 million residents who are also facing gaps in musculoskeletal care. In Singapore, care has been described as "fragmented" (Ong *et al*., 2018), with multiple providers and a focus on specialist or tertiary care. In addition, the rapidly ageing society has already contributed to long wait times and high hospital occupancy levels (Lim *et al*., 2016) and this will increase the burden of musculoskeletal conditions, services and funding for such conditions are typically disease- and anatomical site-focused. Hence, Singapore faces gaps in care fragmentation, increased care burden and a disease-centric model of musculoskeletal care.

Research aims

Given the gaps in this sector, we sought to develop a framework to conceptualise and organise musculoskeletal and physical health, by synthesising existing relevant concepts and frameworks from diverse fields. Thereafter, we apply our framework to areas of practical need, including clinical, policy and research applications. We employ a theoretical synthetic approach to craft an integrated, life-course approach to musculoskeletal and physical health across care settings and levels. Thereafter, this framework can be applied to pressing needs and gaps in the system to improve the holistic health of individuals across their life-course continuum, not just locally, but in diverse contexts as well.

Methods

In developing a life-course framework to improve musculoskeletal health practice and research, we first began with the current state of affairs, finding current approaches to musculoskeletal and physical health episodic, medicalised, overly focused on procedures (Bunzli *et al*., 2021), divided by anatomical sites (National Academies of Sciences *et al*., 2020) and lacking integration (Chehade *et al*., 2020). These gaps reveal a need for holistic,

integrated care approaches that expand beyond medical procedures and encompass individuals' and populations' life-course. Medical care only accounts for 10–20% of the modifiable factors impacting a population's health, with the rest attributed to lifestyle behaviours, physical environment and socioeconomic factors (World Health Organization, 2008).

The authors then entered two phases in developing the novel integrated life-course approach to musculoskeletal and physical health in Singapore. In the first phase, a search was undertaken in multiple databases for existing frameworks and models from diverse fields helpful in targeting the identified gaps in the ecosystem. That is, such approaches should champion integrated care (rather than episodic care), encompass the life-course (not just focused disease) and invite interventions across the social determinants of health (not merely procedural interventions). Keywords for the search included "concept/framework, integrated care, musculoskeletal/physical health, holistic user journey, coordinated models, and comprehensive systems", with the following databases canvassed: MEDLINE (medical, nursing and allied health), ABI/INFORM (business and related domains), Web of Science (science and social science) and Scopus (science, engineering and social science). We included English-language journal articles, books and book chapters regarding frameworks relating to integrated, holistic health or user journeys, and systems or care integration and coordination. Frameworks which could not be applied to a musculoskeletal or physical health ecosystem were excluded. The top results underwent extensive discussion and alignment among authors, who are members of an expert clinical workgroup focusing on physical and musculoskeletal health in Singapore.

In the next phase, the authors discussed to shortlist and synthesise the most relevant concepts to include in the eventual framework. In the field of public policy, theoretical synthesis allows aspects of multiple theories to be combined into one (John, 1998), explaining complex phenomena and relationships between existing theories. A theoretical synthetic approach was adopted to combine the best aspects of the life-course approach (National Healthcare Group, 2019), WHO-endorsed International Classification of Functioning Disability and Health (ICF) model (World Health Organization, 2001), and systems theory (Anderson *et al*., 1999) into a single framework, resulting in a life-course and integrated approach to musculoskeletal health. This is further elaborated in the next section.

Results

The resulting integrated musculoskeletal health life-course framework (see Figure 1) has the following five key distinctive features:

(1) A life-course approach to musculoskeletal health is understood in the broader context of physical health, illustrated by a physical health travellator.

(2) Movement from a disease-based or anatomical perspective towards a more holistic patient-centred functional perspective.

(3) Demonstration of the body structure/function and the interaction with activity levels and social participation in alignment with the ICF model (World Health Organization, 2001).

(4) Recognition of the increasing metabolic and mental health issues that often accompany worsening musculoskeletal and physical health.

(5) Identification of opportunities for integration in intervention, health promotion strategies and clinical and community partners across the primary-secondary-tertiary prevention continuum.

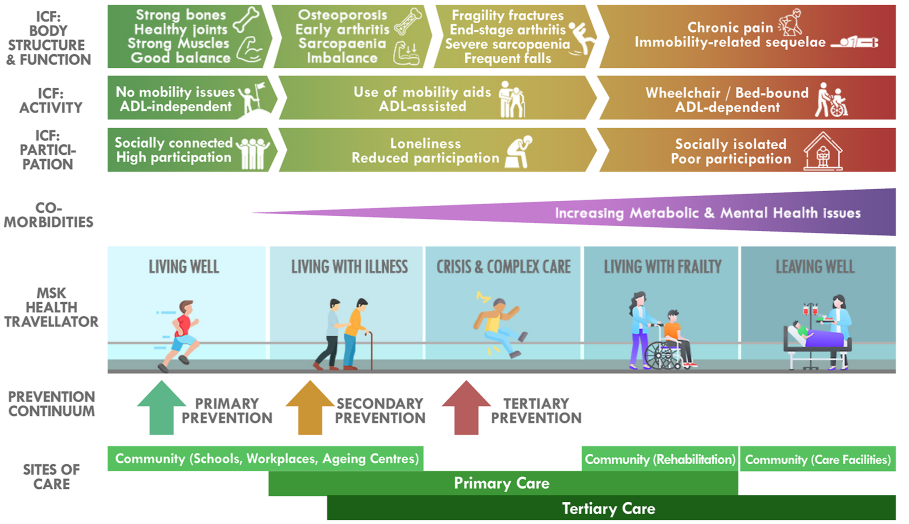


Figure 1. Integrated musculoskeletal health life-course framework

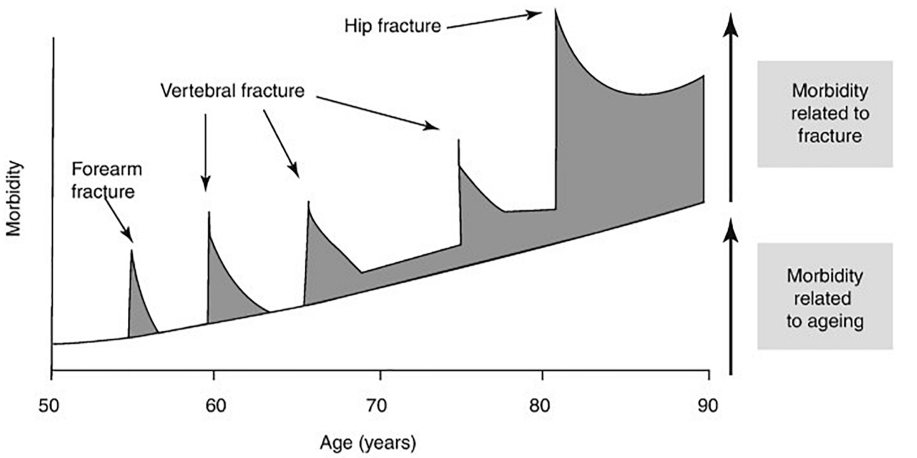
(1) Life-course approach to musculoskeletal and physical health

Life-course approaches consider how temporal processes (such as ageing or crises) interact and impact population-level outcomes, thereby identifying time points of vulnerability where interventions can best help people and communities, potentially even prior to illness (Kuh and Ben-Shlomo, 2004). Life-course research originated from sociological study into family and population changes over time (Elder *et al*., 2003), and over decades evolved to incorporate age, life stages and even illness as the approach was adapted in other various domains and disciplines, including consumer behaviour, public health and ageing (Mayer, 2009; Kuh *et al*., 2014).

There have been several examples of the use of a life-course approach in musculoskeletal health. In osteoporosis and fragility fractures, the fragility fracture life-course described where a forearm or wrist fracture in one's fifties may have short-term recoverable morbidity, but repeated fragility fractures at later ages may result in and irreversible permanent morbidity (Kanis and Johnell, 1999), as seen in Figure 2.

In osteoarthritis, a lifespan approach has been similarly proposed for osteoarthritis management and prevention (Whittaker *et al*., 2021). This has allowed actionable strategies on modifiable risk factors such as physical activity and weight loss, identification of areas lacking evidence, and insights of how prevention via a lifespan approach such as injury prevention, occupational considerations and sarcopenia might change osteoarthritis as an illness rather than an inevitable state of ageing. In muscle health, sarcopenia has been shown to be associated with all-cause mortality. The concept of strengthspan and lifespan (Figure 3) has been promoted to advocate for regular participation in muscle strengthening activities early in life to build and preserve muscle strength rather than a narrow perspective to integrate strength building later in the life, within the geriatric population when disease and disability has set in Faigenbaum *et al*. (2024).

Based on life-course approaches as explored above, we shift away from specific disorders to conceptualise the entirety of the physical health continuum as a River of Life via a travellator analogy. The River of Life framework originates from the National Healthcare Group, a healthcare cluster in Singapore, that incorporates determinants of health beyond an individual's health status to help predict risks, population care need and resource allocation (National Healthcare Group, 2019). The River of Life features five care segments – Living Well, Living with Illness, Crisis and Complex Care, Living with Frailty and Leaving Well (National Healthcare Group, 2019). Our framework borrows these five segments from the River of Life



Source(s): Adapted from Journal of Endo Investigation (1999), Kanis JA and Johnell O

Figure 2. Fragility fracture life-course by Kanis and Johnell (1999)

framework, synthesising them with a life-course perspective, creating the travellator illustration in our framework. These are visualised with helpful pictograms of the physical health status of individuals progressing on a travellator from Living Well (engaging in vigorous activity) to Living with Illness (accruing a condition such as osteoarthritis) to Crisis and Complex Care (such as suffering a fall) to Living with Frailty (a state of increased vulnerability) to Leaving Well (end of life). This travellator facilitates the design of targeted health programs at all stages of the population's life journey, enabling better integration of health and social or ancillary services.

(2) Shifting the focus from anatomy/disease to the person

The current emphasis of musculoskeletal care on anatomical-based pathology and diagnostic algorithms leads to episodic and isolated treatments, often leading to procedure-related interventions that may not provide holistic, whole-of-person care. There is increasing evidence of the discordance that exist between objective clinical and radiological parameters with patient reported pain and disability (Finan *et al*., 2013). It is important to understand the differences between the disease (patient reported experience of the disease) and illness (clinical severity) with evidence suggesting that extent of illness is what drives the personal

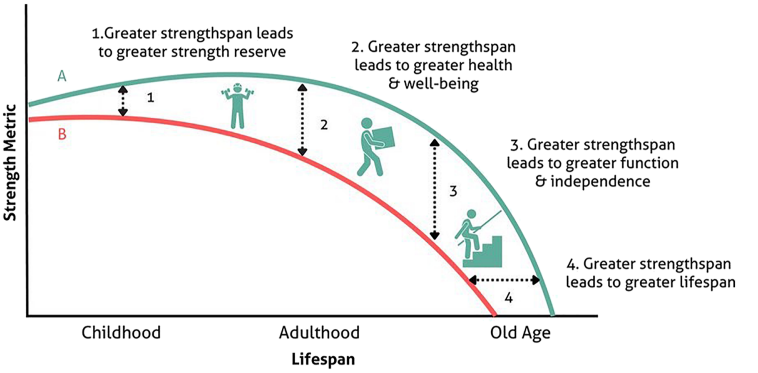


Figure 3. Strengthspan and lifespan metrics by Faigenbaum *et al*. (2024)

and societal burden and cost rather than the severity of disease (Whittaker *et al*., 2021). Understanding the limitation of an anatomical orientated perspective, we advocate moving away from a pure anatomical viewpoint to a more patient-centred, functional perspective that allows policymakers and clinicians to conceive of more holistic and patient-driven outcomes. This produces strategies and programmes emphasising holistic care that restores function and livelihoods, rather than just fixing body parts.

(3) Body function intertwined with activity levels and social participation

The WHO-endorsed International Classification of Functioning, Disability and Health (ICF) (see Figure 4) added the domains of activity and participation to the traditional understanding of physical function and structure, which enabled more collaborative care that enhanced social functioning (Hudson *et al*., 2016). The ICF framework also integrated environmental and personal factors. The ICF has been applied in a variety of fields like psychiatry (Álvarez, 2012) and rehabilitation medicine (Leonardi *et al*., 2022), allowing clinicians to define and examine the impact of activity and participation (or lack thereof) on function and disability, and vice-versa.

Physical function and musculoskeletal health can be intimately intertwined with activity levels and social participation (Seaton and Brown, 2018). If an elderly patient suffers a fragility hip fracture, one might have a period of limited mobility requiring aids, inhibiting activities of daily living; concomitantly, participation in social life is hampered. This may create a negative spiral of impaired body function leading to poorer activity and participation, and vice-versa. Even if there was no significant physical morbidity from a fall such as a fracture, there is often unseen psychological consequences such as a fear of falling that patients develop post-fall (De Roza *et al*., 2022).

This fear of falling can result in a vicious cycle as seen in Figure 5, where fear of falling or self-isolation can cause individuals to reduce their physical activity, which may in turn lead to systemic dysfunction like deconditioning, osteosarcopenia and a resultant increased risk of falls and fractures (Gualano *et al*., 2017). This may further worsen social isolation and inactivity as patients avoid leaving their home, crippled by that fear. With osteoarthritis, a similar picture has been identified with the fear of movement, chronic illness shame and other psychosocial factors significantly affecting patients' mobility and social participation (Yang *et al*., 2023).

Social frailty (among those who go out less frequently, rarely visited or helped friends or family, lived alone or did not talk to another person everyday) was associated with increased

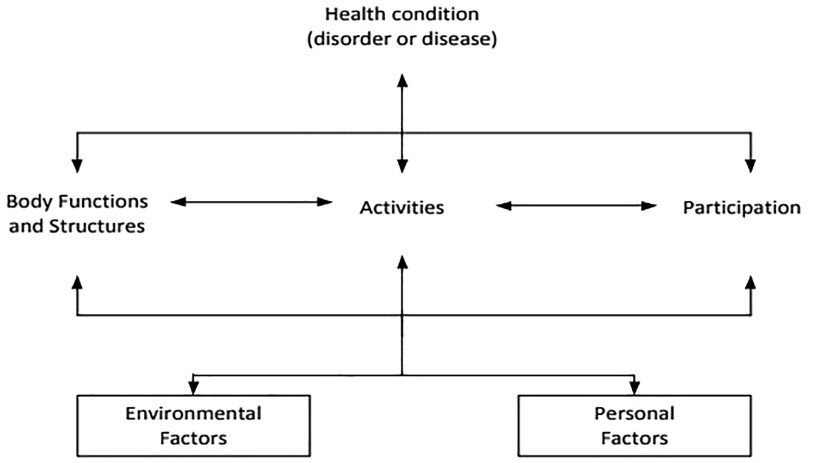


Figure 4. International classification of functioning disability and health (ICF) by World Health Organization (2001)

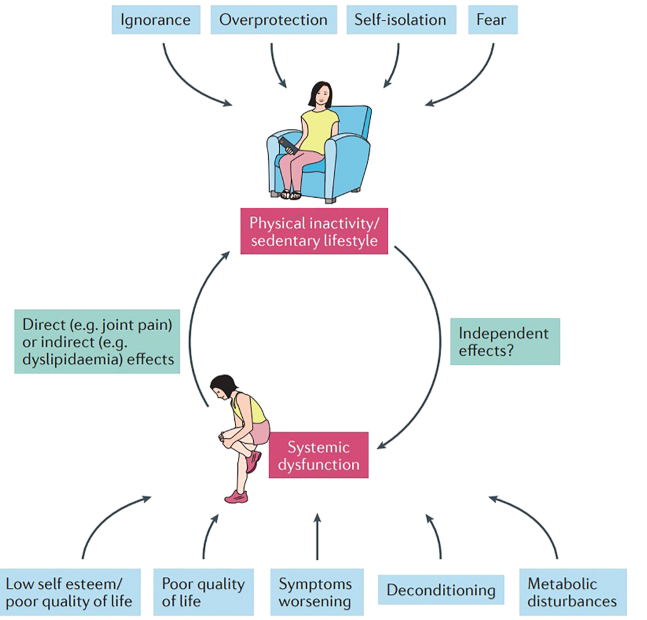


Figure 5. Vicious cycle of physical inactivity and systemic function (Gualano *et al.*, 2017)

risk of developing physical frailty among non-frail adults (Makizako *et al.*, 2018). On the flip side, social participation has been shown to improve functions in those with physical disability (Anaby *et al.*, 2019). These studies show emerging evidence that the link between physiological and social health is real and consequential. Adding the ICF dimensions of activity and participation to a life-course approach further improves the holistic coverage of this framework, by considering additional impact of activity levels and social participation on musculoskeletal health, above and beyond physical structure and function.

(4) Inclusion of associated mental and cardiometabolic health issues

Musculoskeletal health does not merely involve body structure/function, activity level and participation but also mutually impacts frailty and cardiometabolic health. Frailty is often conceived as being physical (such as involving sarcopenia, tiredness and functional loss) but more recent frameworks promote a multidimensional view of frailty, including physical, psychological, cognitive and social dimensions (Wleklik *et al.*, 2020). Poor musculoskeletal health can result in multidimensional impacts: physical and cognitive frailty (Wallace *et al.*, 2019) and social isolation, especially in the elderly (Bevilacqua *et al.*, 2021). Depression and frailty often coexist in older people (Buiguesa *et al.*, 2014), with similar pathophysiological changes and biomarkers observed (Fernández-Garrido *et al.*, 2014). The evidence supporting multidimensional nature of frailty supports this link between physical inactivity, frailty and cognitive/psychological impairment (Sacha *et al.*, 2017). That is, poor musculoskeletal health impacts that physical dimension, which then further impacts the psychological dimension, and social dimension as well, all of which contribute to overall frailty (see Figure 6).

Metabolic health is also implicated as seen in the endocrine and cardiovascular aspects of physical reserves affected by the shared mechanisms causing frailty and cognitive impairments. Studies have demonstrated that impaired mobility, osteoarthritis, sarcopenia and physical inactivity have been linked with obesity, diabetes and cardiovascular disease and all-cause mortality (Park *et al.*, 2023; Biolo *et al.*, 2005; Faigenbaum *et al.*, 2024). This is

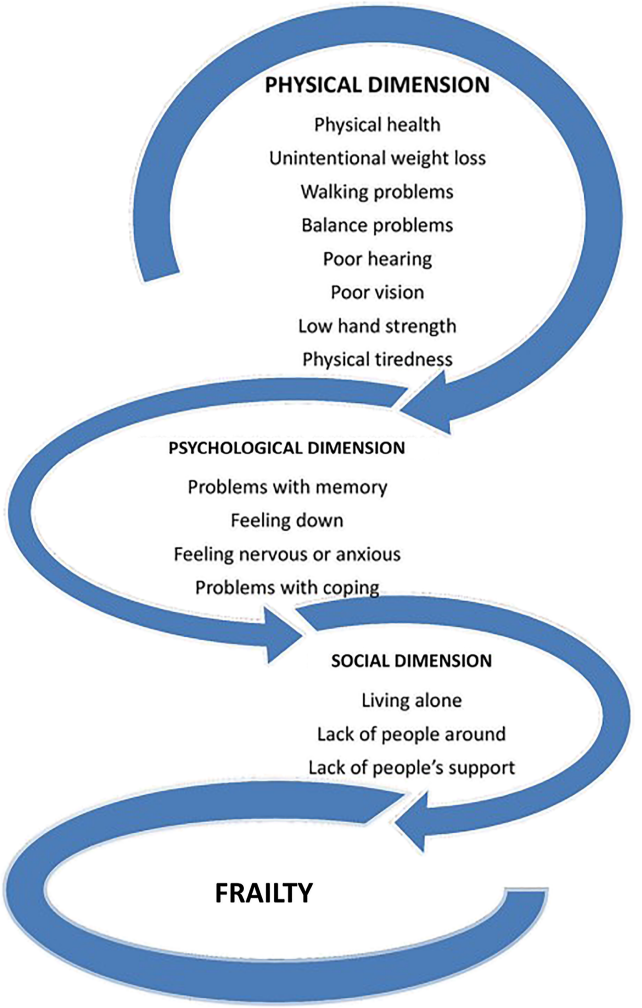


Figure 6. Multidimensional concept of frailty by Sacha *et al.* (2017)

demonstrated in our framework via the increasing triangle of mental and metabolic health issues in tandem with an individual's journey across the life-course travellator.

(5) Enabling integrated care opportunities for primary, secondary and tertiary prevention

Conceptualising the breadth and interplay of determinants of musculoskeletal health across the life-course additionally visualises where opportunities for targeted interventions are available along primary, secondary or tertiary prevention principles aligned with integrated care. The bottom of Figure 1 illustrates where such interventions may target individuals and communities along the travellator continuum, and also which care sites would be involved (in green). Primary prevention including community education on diet and physical activity can help individuals keep Living Well, while secondary prevention screening can identify pre-frail populations early to allow targeted exercise and social support programmes to prevent progression to frailty. When in Crisis and Complex Care or Living with Frailty, tertiary

prevention such as post-fall multidisciplinary rehabilitation can manage sequelae and maximise function while helping patients transition back to their homes and communities. Furthermore, collaboration and integrated pathways across the different levels would create synergistic interventions that minimise roadblocks and duplication of care, instead allowing seamless patient-centred care at any point of the patients' care journey.

Contribution to existing literature

Our framework meets gaps in current approaches to musculoskeletal and physical health. As highlighted earlier, musculoskeletal care is characterised by a focus on individual body parts and symptoms (National Academies of Sciences *et al*., 2020), resulting in episodic, siloed care (Bunzli *et al*., 2021) featuring a lack of communication between these services (Kobayashi *et al*., 2022), and poor coordination across the wider ecosystem (Chehade *et al*., 2020).

A life-course approach would help shift focus back to holistic care of the person (Kuh *et al*., 2014), rather than their body part(s). Where traditionally patients might encounter single episodes of medical care focused on surgeries or procedures only when symptomatic, our approach would allow healthcare staff, policymakers and patients themselves to conceive of more holistic, integrated health solutions that contribute to improved health outcomes and ecosystem benefits. The following section demonstrates results of applying our novel framework to several use cases, from integrated care strategies in population health to cross-disciplinary research and policy plans.

Discussion

Framework application

In response to current gaps in approaches to musculoskeletal and physical health, such as siloed, episodic care and a focus on disease or anatomy rather than the entire person and their place in wider society, we synthesised existing frameworks including a life-course approach, WHO ICF framework, and multidimensional concepts of frailty, to develop an integrated musculoskeletal life-course framework. The framework conceptualises and facilitates collaboration at multiple levels, including health services planning and clinical services, incorporates dimensions of body structure and function, activity and participation, along a physical health travellator illustrating states of health and opportunities for intervention. Taking a life-course approach emphasises the key message that prevention is the predominant overarching strategy for any healthcare policy addressing musculoskeletal health, moving away from healthcare provision to health promotion. Significant efforts are needed to take a "proactive" approach in promote musculoskeletal "health" early in a person's life as compared to a "reactive" approach where we seek to treat musculoskeletal "disease" only when symptoms have surfaced, causing pain and impairing function. Such strategies have been well recognised in other conditions such as diabetes and cardiovascular disease but remain sorely lacking in musculoskeletal health. The following subsections describe particular use cases where our framework has been and can be applied, to bring improvements to the musculoskeletal health ecosystem, not just locally but potentially in other contexts as well.

Guiding macro-meso-micro-level integrated care strategies

In Singapore, there has been a major health policy change to improve population health in the face of a rapidly ageing society (Rangaswamy *et al*., 2021) driven by the government-led initiative "Healthier SG", conceived to centre care practices and policies around preventive health (Foo *et al*., 2023). However, despite healthcare lauded as "affordable excellence" (Haseltine, 2013) and multiple national health promotion initiatives (Foo *et al*., 2023), a decreasing proportion of Singaporeans are achieving sufficient physical activity (Ministry of Health, 2022). Hence, this life-course approach to musculoskeletal and physical health can

identify larger policy directions to help improve the overall ecosystem, organisational and research strategies for more impactful outcomes, and targeted integrated care programmes for effective care. A multidisciplinary, integrated care approach is needed as in many cases, no one specific discipline is able to provide all-encompassing holistic care. Within the musculoskeletal health ecosystem, we have a wide range of healthcare providers including orthopaedic surgeons, physiotherapists, sports medicine practitioners, rehabilitation physicians and rheumatologists. With the increasing recognition of the psychological and mental aspect of musculoskeletal disease, integrating psychological support services have also been advocated as an integrated care model (Zale *et al*., 2018).

Of specific note, integrated care models do not and should not be confined within the traditional healthcare delivery modes. The framework seeks to clearly demonstrate the relationship between the health and social aspect of musculoskeletal health. It is imperative that any integrated care model involves a close partnership with social agencies and community partners on the ground to address things like social isolation beyond addressing the healthcare aspect of their condition. By identifying appropriate partners across the primary-secondary-tertiary prevention continuum through this framework, appropriate integrated care models together with appropriate funding and financing enablers can be developed to ensure that preventive efforts are done by the right team at the right time in the most cost-effective way as possible.

This is illustrated in the application of our integrated musculoskeletal life-course framework to improve care for patients with osteoarthritis through an initiative titled "Collaborative Model of Care between Orthopaedics and Allied Healthcare Professionals for Knee Osteoarthritis" (CONNACT Plus). CONNACT Plus eschews the traditional acute episodic view of osteoarthritis and takes a patient-centred approach with an emphasis on self-management. Physiotherapy, orthopaedics, dietetics and nutrition, and psychology and social services are synergised to optimise rehabilitative outcomes for patients with osteoarthritis, minimising the need for unnecessary surgery (Tan *et al*., 2020). CONNACT Plus integrates patient pathways from tertiary/hospital to community care, through direct referral of patients from tertiary settings to community rehabilitation programmes near their homes, with resultant productivity gains (Tan *et al*., 2024). Our framework helps CONNACT Plus and similar programmes play their unique role as care integrators in the musculoskeletal and physical health ecosystem, synthesising new care pathways and improving patients' outcomes.

While designed with Singapore in mind, our framework's key principles can be applied to any healthcare system and contextualised, particularly when it comes to opportunities for intervention where the health system (e.g. primary, secondary, tertiary, community care) might be set up differently. Policymakers and healthcare staff need only modify sites of care and care pathways to local contexts, while mapping health initiatives and interventions to the health "travellator" life course.

Driving cross-disciplinary research agenda and promoting educational efforts

Beyond planning for integrated care models, this framework can be used to drive the research agenda and promote educational efforts. It is important that research efforts go beyond the traditional biomedical research in musculoskeletal diseases towards understanding the often-complex relationships with activity levels, social participation, mental and metabolic health. This will allow a better appreciation of the true impact and burden of musculoskeletal disease and guide the better integration of care across the various disciplines. Better and more accurate screening and stratification tools developed through robust research methodologies can be used to plan the prudent use of resources to target the high-risk subpopulations for more targeted intervention programs. With the emphasis on prevention, a long-term perspective is needed when it comes to tracking patient outcomes as preventive efforts may not see tangible results until years later. Modelling is a useful tool to predict the long-term effectiveness of preventive efforts to support initial funding and investment.

Education efforts ideally should target both the healthcare providers level and the patient/general population level. At the healthcare provider level, there is a need to raise the awareness of the impact of musculoskeletal disease with activity levels, social participation, mental and metabolic health. This will highlight the clear need for different disciplines to work together, breaking down the traditional barriers and promoting integrated care. For example, at the general public level, broad educational efforts promoting the critical role of physical activity, weight management and other risk factors for musculoskeletal health coupled with a mind-set shift away from musculoskeletal "wear and tear" disease as an inevitable part of ageing, will promote active ageing in society, maintaining mobility and function for the larger population as long as possible. As no individual specialty or actor owns population musculoskeletal health promotion currently, possible ways forward include governmental agencies taking up the mandate, or a coalition of healthcare organisations seeing the value to the overall ecosystem through our framework and doing so.

Strengths and limitations

The authors acknowledge that strict systematic or scoping review methodology was not employed in this concept paper, so some relevant frameworks may have inadvertently been missed. Nevertheless, we have endeavoured to be inclusive in canvassing multiple disciplines across different databases with keywords and inclusion/exclusion criteria, and supplemented this with key expert opinions. This approach is consistent with other framework or conceptual development papers (Kim *et al*., 2006; Cooper and Gibson, 2022).

As a result, we have developed a novel framework approach to musculoskeletal and physical health, which includes principles of holistic, integrated care that follows individuals across their life-course and can link services and efforts across the care continuum and different care sites. Applying our framework can help clinicians, policymakers and researchers as mentioned in the use cases above coordinate efforts and develop synergies as they link services across settings for more seamless care of individuals. This can overcome current challenges of episodic care overly-focused on anatomical issues or procedures, and a lack of care integration that may hamper individuals' access to services and optimal physical health. To our knowledge, such an approach has not been strongly established in the musculoskeletal and physical health area, so this paper contributes a novel approach to improve the ecosystem.

Conclusion

Musculoskeletal conditions present a significant care and disability burden on our societies, and current approaches focusing on specific diseases or anatomical sites result in episodic, siloed care. We therefore developed and implemented a framework and approach that (1) takes a life-course view of musculoskeletal and physical health, (2) shifts focus away from an anatomical perspective to functional, (3) encompasses activity and participation in addition to body structure/function, (4) demonstrates the associated mental and metabolic health issues and (5) highlights opportunities for primary, secondary and tertiary integrated interventions at different levels and care sites. This life-course approach can be applied to guide macro-meso-micro integrated care strategies, drive research agenda and promote educational efforts for better musculoskeletal and physical health.

References

Álvarez, A.S. (2012), "The application of the international classification of functioning, disability, and health in psychiatry", *American Journal of Physical Medicine and Rehabilitation*, Vol. 91 No. 13, pp. S69-S73, doi: 10.1097/phm.0b013e31823d4f1c.

Anaby, D., Avery, L., Gorter, J.W., Levin, M.F., Teplicky, R., Turner, L., Cormier, I. and Hanes, J. (2019), "Improving body functions through participation in community activities among young people with physical disabilities", *Developmental Medicine and Child Neurology*, Vol. 62 No. 5, pp. 640-646, doi: 10.1111/dmcn.14382.

Anderson, R.E., Carter, I. and Lowe, G.R. (1999), *Human Behavior in the Social Environment*, Aldine de Gruyter, New York.

Ball, K., Carver, A., Downing, K., Jackson, M. and O'rourke, K. (2015), "Addressing the social determinants of inequities in physical activity and sedentary behaviours", *Health Promotion International*, Vol. 30 No. suppl 2, pp. ii8-ii19, doi: 10.1093/heapro/dav022.

Bevilacqua, G., Jameson, K.A., Zhang, J., Bloom, I., Ward, K.A., Cooper, C. and Dennison, E.M. (2021), "The association between social isolation and musculoskeletal health in older community-dwelling adults: findings from the Hertfordshire Cohort Study", *Quality of Life Research*, Vol. 30 No. 7, pp. 1913-1924, doi: 10.1007/s11136-021-02784-7.

Biolo, G., Ciocchi, B., Stulle, M., Piccoli, A., Lorenzon, S., Mas, V.D., Barazzoni, R., Zanetti, M. and Guarnieri, G. (2005), "Metabolic consequences of physical inactivity", *Journal of Renal Nutrition*, Vol. 15 No. 1, pp. 49-53, doi: 10.1053/j.jrn.2004.09.009.

Buiguesa, C., Padilla-Sánchez, C., Garrido, J.F., Martínez, R.N., Ros, V.R. and Cauli, O. (2014), "The relationship between depression and frailty syndrome: a systematic review", *Aging and Mental Health*, Vol. 19 No. 9, pp. 762-772, doi: 10.1080/13607863.2014.967174.

Bunzli, S., Taylor, N., O'brien, P., Dowsey, M., Wallis, J., Choong, P. and Shields, N. (2021), "How do people communicate about knee osteoarthritis? A discourse analysis", *Pain Medicine*, Vol. 22 No. 5, pp. 1127-1148, doi: 10.1093/pm/pnab012.

Chehade, M.J., Yadav, L., Kopansky-Giles, D., Merolli, M., Palmer, E., Jayatilaka, A. and Slater, H. (2020), "Innovations to improve access to musculoskeletal care", *Best Practice and Research Clinical Rheumatology*, Vol. 34 No. 5, 101559, doi: 10.1016/j.berh.2020.101559.

Chen, N., Fong, D.Y.T. and Wong, J.Y.H. (2023), "Health and economic outcomes associated with musculoskeletal disorders attributable to high body mass index in 192 countries and territories in 2019", *JAMA Network Open*, Vol. 6 No. 1, e2250674, doi: 10.1001/jamanetworkopen.2022.50674.

Clark, P.M. and Ellis, B.M. (2014), "A public health approach to musculoskeletal health", *Best Practice and Research Clinical Rheumatology*, Vol. 28 No. 3, pp. 517-532, doi: 10.1016/j.berh.2014.10.002.

Cooper, K.J. and Gibson, R.B. (2022), "A novel framework for inner-outer sustainability assessment", *Challenges*, Vol. 13 No. 2, p. 64, doi: 10.3390/challe13020064.

De Roza, J.G., Ng, D.W.L., Mathew, B.K., Jose, T., Goh, L.J., Wang, C., Soh, C.S.C. and Goh, K.C. (2022), "Factors influencing fear of falling in community-dwelling older adults in Singapore: a cross-sectional study", *BMC Geriatrics*, Vol. 22 No. 1, p. 186, doi: 10.1186/s12877-022-02883-1.

Edwardson, C.L., Gorely, T., Davies, M.J., Gray, L.J., Khunti, K., Wilmot, E.G., Yates, T. and Biddle, S.J.H. (2012), "Association of sedentary behaviour with metabolic syndrome: a meta-analysis", *PLoS One*, Vol. 7 No. 4, e34916, doi: 10.1371/journal.pone.0034916.

Elder, G.H. Jr, Johnson, M.K. and Crosnoe, R. (2003), "The emergence and development of life course theory", in Mortimer, J.T. and Shanahan, M.J. (Eds), *Handbook of the Life Course*, Kluwer Academic/Plenum, New York.

Faigenbaum, A.D., Garcia-Hermoso, A., Macdonald, J.P., Mortatti, A. and Rial Rebullido, T. (2024), "Bridging the gap between strengthspan and lifespan", *British Journal of Sports Medicine*, Vol. 58 No. 14, pp. 758-760, doi: 10.1136/bjsports-2024-108357.

Fernández-Garrido, J., Navarro-Martínez, R., Buigues-González, C., Martínez-Martínez, M., Ruiz-Ros, V. and Cauli, O. (2014), "The value of neutrophil and lymphocyte count in frail older women", *Experimental Gerontology*, Vol. 54, pp. 35-41, doi: 10.1016/j.exger.2013.11.019.

Finan, P.H., Buenaver, L.F., Bounds, S.C., Hussain, S., Park, R.J., Haque, U.J., Campbell, C.M., Haythornthwaite, J.A., Edwards, R.R. and Smith, M.T. (2013), "Discordance between pain and radiographic severity in knee osteoarthritis: findings from quantitative sensory testing of central sensitization", *Arthritis and Rheumatism*, Vol. 65 No. 2, pp. 363-372, doi: 10.1002/art.34646.

Foo, C.D., Chia, H.X., Teo, K.W., Farwin, A., Hashim, J., Koh, G. C.-H., Matchar, D.B., Legido-Quigley, H. and Yap, J.C.H. (2023), "Healthier SG: Singapore's multi-year strategy to transform

primary healthcare", *The Lancet Regional Health - Western Pacific*, Vol. 37, 100861, doi: 10.1016/j.lanwpc.2023.100861.

Gualano, B., Bonfa, E., Pereira, R.M.R. and Silva, C.A. (2017), "Physical activity for paediatric rheumatic diseases: standing up against old paradigms", *Nature Reviews Rheumatology*, Vol. 13 No. 6, pp. 368-379, doi: 10.1038/nrrheum.2017.75.

Guan, S.-Y., Zheng, J.-X., Sam, N.B., Xu, S., Shuai, Z. and Pan, F. (2023), "Global burden and risk factors of musculoskeletal disorders among adolescents and young adults in 204 countries and territories, 1990-2019", *Autoimmunity Reviews*, Vol. 22 No. 8, 103361, doi: 10.1016/j.autrev.2023.103361.

Haseltine, W. (2013), *Affordable Excellence: the Singapore healthcare Story: How to Create and Manage Sustainable Healthcare Systems*, NUS Press, Singapore.

Heikkinen, J., Honkanen, R., Williams, L., Leung, J., Rauma, P., Quirk, S. and Koivumaa-Honkanen, H. (2019), "Depressive disorders, anxiety disorders and subjective mental health in common musculoskeletal diseases: a review", *Maturitas*, Vol. 127, pp. 18-25, doi: 10.1016/j.maturitas.2019.05.011.

Hudson, J.L., Bower, P., Archer, J. and Coventry, P.A. (2016), "Does collaborative care improve social functioning in adults with depression? The application of the WHO ICF framework and meta-analysis of outcomes", *Journal of Affective Disorders*, Vol. 189, pp. 379-391, doi: 10.1016/j.jad.2015.09.034.

Jinks, C., Botto-Van Bemden, A., Bunzli, S., Bowden, J., Egerton, T., Eyles, J., Foster, N., Healey, E.L., Maddison, J., O'brien, D., Quicke, J.G., Schiphof, D., Parry, E., Thomas, M.J. and Holden, M.A. and Change Oa Narrative (Coan) Initiative (2023), "Changing the narrative on osteoarthritis: a call for global action", *Osteoarthritis and Cartilage*, Vol. 32, pp. 414-420.

Johansen, I., Klokkerud, M., Anke, A., Børke, J.-B., Glott, T., Hauglie, U., Høyem, A., Klovning, A., Lande, K.A., Larsen, M., Nordvik, J.E., Wigers, S.H., Øyeflaten, I., Hagen, K.B. and Kjeken, I. (2019), "A quality indicator set for use in rehabilitation team care of people with rheumatic and musculoskeletal diseases; development and pilot testing", *BMC Health Services Research*, Vol. 19 No. 1, 265, doi: 10.1186/s12913-019-4091-4.

John, P. (1998), *Analysing Public Policy*, Continuum, London.

Joshipura, M. and Gosselin, R.A. (2018), "Surgical burden of musculoskeletal conditions in low and middle-income countries", *World Journal of Surgery*, Vol. 44 No. 4, pp. 1026-1032, doi: 10.1007/s00268-018-4790-8.

Kanis, J.A. and Johnell, O. (1999), "The burden of osteoporosis", *Journal of Endocrinological Investigation*, Vol. 22 No. 8, pp. 583-588, doi: 10.1007/bf03343614.

Kim, S., Phillips, W.R., Pinsky, L., Brock, D., Phillips, K. and Keary, J. (2006), "A conceptual framework for developing teaching cases: a review and synthesis of the literature across disciplines", *Medical Education*, Vol. 40 No. 9, pp. 867-876, doi: 10.1111/j.1365-2929.2006.02544.x.

Kobayashi, S., Allen, K., Bennell, K., Bowden, J.L., Briggs, A.M., Burgess, A., Hinman, R.S., Holden, M., Østerås, N., Risberg, M.a. G., Sharma, S., Esch, M.V.D. and Eyles, J.P. (2022), "A framework to guide the development of health care professional education and training in best evidence osteoarthritis care", *Clinics in Geriatric Medicine*, Vol. 38 No. 2, pp. 361-384, doi: 10.1016/j.cger.2021.11.008.

Kuh, D. and Ben-Shlomo, Y. (2004), "Introduction", in Kuh, D. and Ben-Shlomo, Y. (Eds), *A Life Course Approach to Chronic Disease Epidemiology*, Oxford University Press, Oxford.

Kuh, D., Karunananthan, S., Bergman, H. and Cooper, R. (2014), "A life-course approach to healthy ageing: maintaining physical capability", *Proceedings of the Nutrition Society*, Vol. 73 No. 2, pp. 237-248, doi: 10.1017/s0029665113003923.

Leonardi, M., Lee, H., Kostanjsek, N., Fornari, A., Raggi, A., Martinuzzi, A., Yáñez, M., Almborg, A.-H., Fresk, M., Besstrashnova, Y., Shoshmin, A., Castro, S.S., Cordeiro, E.S., Cuenot, M., Haas, C., Maart, S., Maribo, T., Miller, J., Mukaino, M., Snyman, S., Trinks, U., Anttila, H., Paltamaa, J., Saleeby, P., Frattura, L., Madden, R., Sykes, C., Gool, C.H.V., Hrkal, J., Zvolský, M., Sládková, P., Vikdal, M., Harðardóttir, G.A., Foubert, J., Jakob, R., Coenen, M. and Camargo,

O.K.D. (2022), "20 Years of ICF—international classification of functioning, disability and health: uses and applications around the World", *International Journal of Environmental Research and Public Health*, Vol. 19 No. 18, 11321, doi: 10.3390/ijerph191811321.

Lim, K.K., Chan, M., Navarra, S., Haq, S.A. and Lau, C.S. (2016), "Development and implementation of Models of Care for musculoskeletal conditions in middle-income and low-income Asian countries", *Best Practice and Research Clinical Rheumatology*, Vol. 30 No. 3, pp. 398-419, doi: 10.1016/j.berh.2016.08.007.

Makizako, H., Shimada, H., Doi, T., Tsutsumimoto, K., Hotta, R., Nakakubo, S., Makino, K. and Lee, S. (2018), "Social frailty leads to the development of physical frailty among physically non-frail adults: a four-year follow-up longitudinal cohort study", *International Journal of Environmental Research and Public Health*, Vol. 15 No. 3, p. 490, doi: 10.3390/ijerph15030490.

Mayer, K.U. (2009), "New directions in life course research", *Annual Review of Sociology*, Vol. 35 No. 1, pp. 413-433, doi: 10.1146/annurev.soc.34.040507.134619.

Ministry of Health (2022), *National Population Health Survey 2022*, MOH, Singapore.

National Academies of Sciences, E., And Medicine, Division;, H.a. M., Services, B.O.H.C. and Treatment, C.O.I.D.M.C.L.T.I.W. (2020), "Musculoskeletal disorders", in *Selected Health Conditions and Likelihood of Improvement with Treatment*, National Academies Press (US), Washington, DC.

National Healthcare Group (2019), *River of Life: NHG's Perspectives on Population Health*, NHG, Singapore.

Nguyen, A.T., Aris, I.M., Snyder, B.D., Harris, M.B., Kang, J.D., Murray, M., Rodriguez, E.K. and Nazarian, A. (2024), "Musculoskeletal health: an ecological study assessing disease burden and research funding", *The Lancet Regional Health - Americas*, Vol. 29, 100661, doi: 10.1016/j.lana.2023.100661.

Nicolson, P.J.A., Williamson, E., Morris, A., Sanchez-Santos, M.T., Bruce, J., Silman, A. and Lamb, S.E. (2020), "Musculoskeletal pain and loneliness, social support and social engagement among older adults: analysis of the Oxford Pain, Activity and Lifestyle cohort", *Musculoskeletal Care*, Vol. 19 No. 3, pp. 269-277, doi: 10.1002/msc.1526.

Ong, S.E., Tyagi, S., Lim, M.J., Chia, S.K. and Legido-Quigley, H. (2018), "Health systems reforms in Singapore: A qualitative study of key stakeholders", *Health Policy*, Vol. 122 No. 4, pp. 431-443, doi: 10.1016/j.healthpol.2018.02.005.

Park, D., Park, Y.-M., Ko, S.-H., Choi, Y.-H., Min, D.-U., Ahn, J.-H., Kim, B., Koh, H.-S. and Han, K. (2023), "Association between knee osteoarthritis and the risk of cardiovascular disease and the synergistic adverse effects of lack of exercise", *Scientific Reports*, Vol. 13 No. 1, p. 2777, doi: 10.1038/s41598-023-29581-1.

Rangaswamy, E., Periyasamy, G. and Nawaz, N. (2021), "A study on Singapore's ageing population in the context of eldercare initiatives using machine learning algorithms", *Big Data and Cognitive Computing*, Vol. 5 No. 4, p. 51, doi: 10.3390/bdcc5040051.

Sacha, J., Sacha, M., Sobon, J., Borysiuk, Z. and Feusette, P. (2017), "Is it time to begin a public campaign concerning frailty and pre-frailty? A review article", *Frontiers in Physiology*, Vol. 8, p. 484, doi: 10.3389/fphys.2017.00484.

Seaton, L. and Brown, T. (2018), "The relationship between body function and structure factors and the activity-participation of healthy community-dwelling older adults", *Physical and Occupational Therapy in Geriatrics*, Vol. 36 Nos 2-3, pp. 121-135, doi: 10.1080/02703181.2018.1443193.

Tan, B.Y., Pereira, M.J., Yang, S.-Y., Hunter, D.J., Skou, S.T., Thumboo, J. and Car, J. (2020), "Collaborative model of care between Orthopaedics and allied healthcare professionals in knee osteoarthritis (CONNACT): study protocol for an effectiveness-implementation hybrid randomized control trial", *BMC Musculoskeletal Disorders*, Vol. 16 No. 1, p. 684, doi: 10.1186/s12891-020-03695-3.

Tan, B.Y., Yang, S.-Y., Pereira, M.J., Tan, C.Y., Lim, C.J., Ng, J.P., Lee, K.T., Pua, Y.H., Briggs, A.M., Hunter, D.J., Skou, S.T., Thumboo, J. and Car, J. (2024), "Collaborative model of care between orthopaedics and allied healthcare professionals (CONNACT) in knee osteoarthritis: effectiveness-implementation hybrid randomized controlled trial of a community-based,

multidisciplinary, stratified intervention", *Osteoarthritis and Cartilage*, Vol. 32 No. 8, pp. 972-981, doi: 10.1016/j.joca.2024.04.018.

Wallace, L., Theou, O., Godin, J., Mk Andrew, D.B. and Rockwood, K. (2019), "Investigation of frailty as a moderator of the relationship between neuropathology and dementia in Alzheimer's disease: a cross-sectional analysis of data from the Rush Memory and Aging Project", *The Lancet Neurology*, Vol. 18 No. 2, pp. 177-184, doi: 10.1016/s1474-4422(18)30371-5.

Whittaker, J.L., Runhaar, J., Bierma-Zeinstra, S. and Roos, E.M. (2021), "A lifespan approach to osteoarthritis prevention", *Osteoarthritis and Cartilage*, Vol. 29 No. 12, pp. 1638-1653, doi: 10.1016/j.joca.2021.06.015.

Wleklik, M., Uchmanowicz, I., Jankowska, E.A., Vitale, C., Lisiak, M., Drozd, M., Pobrotyn, P., Tkaczyszyn, M. and Lee, C. (2020), "Multidimensional approach to frailty", *Frontiers in Psychology*, Vol. 11, 564, doi: 10.3389/fpsyg.2020.00564.

Woods, V. (2005), "Work-related musculoskeletal health and social support", *Occupational Medicine*, Vol. 55 No. 3, pp. 177-189, doi: 10.1093/occmed/kqi085.

World Health Organization (2001), *International Classification of Functioning, Disability and Health*, WHO, Geneva.

World Health Organization (2015), *WHO Global Strategy on People-Centred and Integrated Health Services: Interim Report*, World Health Organization, Geneva.

World Health Organization, C.O.S.D.O.H. (2008), "Closing the gap in a generation: health equity through action on the social determinants of health", in WHO (Ed.), *CSDH Final Report*.

Yang, S.Y., Woon, E.Y.S., Griva, K. and Tan, B.Y. (2023), "A qualitative study of psychosocial factors in patients with knee osteoarthritis: insights learned from an Asian population", *Clinical Orthopaedics and Related Research*, Vol. 481 No. 5, pp. 874-884, doi: 10.1097/corr.0000000000002526.

Zale, E.L., Ring, D. and Vranceanu, A.M. (2018), "The future of orthopaedic care: promoting psychosocial resiliency in orthopaedic surgical practices", *Journal of Bone and Joint Surgery American*, Vol. 100 No. 13, p. e89, doi: 10.2106/jbjs.17.01159.

Author Affiliations

Bryan Yijia Tan, Woodlands Health, Singapore, Singapore and LKCMedicine, Singapore, Singapore

Andrew Ian-Hong Phua, Clinical Academic Division, National Healthcare Group, Singapore, Singapore and MOHH, Singapore, Singapore

Ivy Wei Fang Ho, Clinical Academic Division, National Healthcare Group, Singapore, Singapore

Aidan Lyanzhiang Tan, Health Services and Outcomes Research, National Healthcare Group, Singapore, Singapore

Shieh Yng Lian, Clinical Academic Division, National Healthcare Group, Singapore, Singapore

Clive Tan, Department of Preventive and Population Medicine, Tan Tock Seng Hospital, Singapore, Singapore and Saw Swee Hock School of Public Health, National University Singapore, Singapore, Singapore

Chin Sim Teoh, Sports & Exercise Medicine, Department of Orthopaedic Surgery, Khoo Teck Puat Hospital, Singapore, Singapore

Soon Yin Tjan, Department of Rehabilitation Medicine, Tan Tock Seng Hospital, Singapore, Singapore

Yew Yoong Ding, Department of Geriatric Medicine, Tan Tock Seng Hospital, Singapore, Singapore and Lee Kong Chian School of Medicine, Singapore, Singapore

Tock Han Lim, National Healthcare Group, Singapore, Singapore and NHG Eye Institute, Singapore, Singapore

Corresponding author
Bryan Yijia Tan can be contacted at: bryan_tan@wh.com.sg