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4 **“Build Better Bones”: Development, Launch, and Future Directions of a Multilingual,**
5 **User-Centered Website for Osteoporosis Management**
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9 Daniel Pinto¹, Olivier Bruyère², Mitali Sharma³, Sydney Blomme⁴, Robert D Blank⁵, Bjoern
10 Buehring⁶, Bruno Muzzi Camargos⁷, Roland Chapurlat⁸, Thierry Chevalley⁹, Elaine M
11 Dennison¹⁰, Jean-François Kaux¹¹, Nancy E Lane¹², Osvaldo Daniel Messina¹³, Rene Rizzoli¹⁴,
12 Jorge Morales Torres¹⁵, Julien Paccou¹⁶, Alexandra Papaioannou¹⁷, Jean-Yves Reginster¹⁸,
13 David Scott¹⁹, Sansin Tuzun²⁰, Stuart Silverman²¹, on behalf of the Rehabilitation Working
14 Group of IOF Committee of Scientific Advisors
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17

18 **Affiliation**

- 19 1. Department of Physical Therapy, Marquette University, Milwaukee, USA; WHO
20 Collaborating Center for Epidemiology of Musculoskeletal Health and Aging, Division of
21 Public Health, Epidemiology and Health Economics, University of Liège, Liège, Belgium.
- 22 2. Department of Physical Activity and Rehabilitation Sciences and Research Unit in Public
23 Health, Epidemiology and Health Economics, University of Liège, Liège, Belgium
- 24 3. The OMC Research Center, Beverly Hills, CA, USA
- 25 4. College of Health Sciences, Marquette University
- 26 5. Garvan Institute of Medical Research, Sydney, Australia; Medical College of Wisconsin,
27 Milwaukee, WI
- 28 6. Bergisches Rheuma-Zentrum, Krankenhaus St Josef, Wuppertal, Germany; Rheumazentrum
29 Ruhrgebiet, Ruhr-University Bochum, Bochum, Germany
- 30 7. Densitometry Unit – Rede Materdei de Saúde, Belo Horizonte, Minas Gerais, Brazil
- 31 8. INSERM UMR 1033, Université de Lyon, Hôpital Edouard Herriot, Lyon, France
- 32 9. Division of Bone Diseases, Department of Medicine, University Hospitals and Faculty of
33 Medicine of Geneva, Geneva, Switzerland
- 34 10. MRC Lifecourse Epidemiology Centre, University of Southampton, Southampton, UK
- 35 11. Department of Physical Activity and Rehabilitation Sciences, University of Liège, Liège,
36 Belgium; Physical and Rehabilitation Medicine Department, University Hospital of Liège,
37 Liège, Belgium.
- 38 12. Department of Medicine, U.C. Davis Health, Sacramento, CA, 95817, USA.
- 39 13. Investigaciones Reumatológicas y Osteológicas (IRO). Collaborating Centre WHO, Buenos
40 Aires, Argentina; IRO Medical Center, Investigaciones Reumatológicas y Osteológicas
41 SRL, Buenos Aires, Argentina
- 42 14. Service of Bone Diseases, Geneva University Hospitals and Faculty of Medicine, 1211,
43 Geneva 14, Switzerland.
- 44 15. University of Guanajuato at León, Osteoporosis Unit, Hospital Aranda de La Parra, León,
45 Mexico
- 46 16. Univ. Lille, CHU Lille, MABlab ULR 4490, Department of Rheumatology, 59000 Lille,
47 France
- 48 17. McMaster University, Departments of Medicine and Health Research Methods, Evidence
49 and Impact Hamilton, ON, Canada
- 50 18. Protein Research Chair, Biochemistry Dept, College of Science, King Saud University,
51 Riyadh, Kingdom of Saudi Arabia
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19. Institute for Physical Activity and Nutrition (IPAN), Deakin University, Geelong, Australia; School of Clinical Sciences at Monash Health, Monash University, Clayton, Australia

20. Department of Physical Medicine and Rehabilitation, Cerrahpaşa School of Medicine, Istanbul University- Cerrahpaşa, Istanbul, Turkey

21. The OMC Research Center, Beverly Hills, CA, USA; Cedars-Sinai Medical Center, Los Angeles, CA, USA

Corresponding author: Daniel Pinto, d.pinto@marquette.edu

Conflict of Interest:
Daniel Pinto, Olivier Bruyère, Mitali Sharma, Sydney Blomme, Robert D Blank, Bjoern Buehring, Bruno Muzzi Camargos, Roland Chapurlat, Thierry Chevalley, Elaine M Dennison, Jean-François Kaux, Nancy E Lane, Osvaldo Daniel Messina, Rene Rizzoli, Jorge Morales Torres, Julien Paccou, Alexandra Papaioannou, Jean-Yves Reginster, David Scott, Sansin Tuzun, and Stuart Silverman declare that they have no conflict of interest.

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4 **Abstract**
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7 Introduction: Osteoporosis is a common chronic disease that requires effective self-management,
8 including optimal diet, exercise and home safety practices. The COVID-19 pandemic disrupted
9 traditional outpatient care and increased the need for remote resources. In response, the
10 International Osteoporosis Foundation (IOF) Rehabilitation Working Group developed a web-
11 based platform "Build Better Bones" to support individuals with osteoporosis and their care
12 providers.
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14 Methods: The website's development followed a design thinking, iterative process informed by
15 input from diverse stakeholders, including patients, healthcare professionals, and design experts.
16 Qualitative feedback from 24 stakeholders across three countries shaped the platform's usability
17 and content. Key features include an evidence-based exercise library, practical nutritional
18 guidance, and home safety recommendations. To ensure inclusivity, the site was designed to
19 accommodate a global audience through translation into five languages and culturally diverse
20 animated characters.
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22 Results: Stakeholders emphasized the primacy of site navigation and readability, empowering
23 and inclusive images, and compassionate language. The website provides exercises tailored to
24 the management of osteoporosis, focusing on exercise and nutrition with an emphasis on home
25 safety to minimize the risk of fracture. The inclusion of interactive elements, multilingual
26 support and visually appealing content was guided by stakeholder input. Patients identified the
27 accordion-style presentation and focus on empowering self-management, while clinicians valued
28 the evidence-based exercise recommendations. Qualitative input highlighted the need for
29 inclusive language, accessibility improvements and practical guidance for safe practice at home.
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31 Conclusion: The "Build Better Bones" platform bridges a gap in osteoporosis care by providing
32 evidence-based resources tailored to both clinicians and patients that can be disseminated to a
33 global audience. Iterative stakeholder feedback has ensured that the platform is aligned with user
34 needs, making it scalable and adaptable to real-world conditions. Future efforts will focus on
35 expanding content, improving tailored features and integrating additional languages to serve a
36 global audience.
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41 Mini abstract: The Build Better Bones website was developed using a robust stakeholder-
42 engaged approach to be a self-management resource for people with osteoporosis and for care
43 partners of people with osteoporosis. The website focuses on providing education and resources
44 for exercise, nutrition, home safety, and advice for care partners.
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47 Keywords: Osteoporosis management, Telehealth resources, Patient-centered care, Rehabilitation
48 exercises, Stakeholder engagement
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4 **1. Introduction**
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7 Osteoporosis represents a major global public health concern, characterized by reduced bone mass
8 and structural deterioration of bone tissue, leading to an increased risk of fractures. This condition
9 disproportionately affects older adults, with fractures significantly contributing to disability, loss
10 of independence, and increased healthcare costs. Effective management of osteoporosis requires a
11 multifaceted approach, including evidence informed nutrition, targeted exercises to improve
12 strength and balance, and home safety measures to reduce fall risks (1). These strategies are
13 essential for preserving function, preventing fractures, and enhancing the quality of life of
14 individuals living with osteoporosis (2).
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18 The COVID-19 pandemic brought about unprecedented challenges to healthcare systems
19 worldwide, disrupting outpatient services and reducing access to rehabilitation programs. These
20 disruptions left many individuals with osteoporosis unable to access the care needed to maintain
21 bone health and prevent functional decline (3). This situation underscored the urgent need for
22 innovative solutions to support the self-management of osteoporosis, particularly in the absence
23 of traditional in-person care. Self-management is a cornerstone of osteoporosis care, empowering
24 individuals to actively participate in maintaining their bone health. However, there remains a
25 global gap in access to reliable, evidence-based resources tailored to the needs of individuals with
26 osteoporosis and their caregivers. High-quality online content to support optimal aging in general
27 (e.g., McMaster Optimal Aging Portal) does exist but little detail is provided for the self-
28 management of osteoporosis. Multiple osteoporosis-focused foundation websites have self-
29 management information, but it is often limited to the languages of their constituency, i.e.
30 Osteoporosis Canada has primary content in English and French, Royal Osteoporosis Society has
31 content in English, Bone Health and Osteoporosis Foundation has content in English and Spanish.
32 Recognizing this gap, members of the Rehabilitation Working Group (RWG) of the International
33 Osteoporosis Foundation (IOF), many who also have affiliations in national foundations, realized
34 a need to develop a scalable, accessible tool with high quality self-management information related
35 to osteoporosis education, practical guidance, and support for patients, caregivers, and healthcare
36 providers. The goal of the website is to be able to support translation of knowledge about
37 osteoporosis-related self-management, become a tool to support change in attitudes about self-
38 management with osteoporosis, and to ultimately support behavior change across all end-users.
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44 The RWG developed a plan to create a rehabilitation focused website using a Design Thinking
45 approach with a focus on end-user desires, addressing challenges to best serve remote
46 rehabilitation needs at scale. The intent of the process was to provide early value through iterative
47 software development making novel technology fit for real-world use (4, 5). According to
48 O’Cathain et al., intervention development should be “a dynamic iterative process, involving
49 stakeholders, reviewing published research evidence, drawing on existing theories, articulating
50 program theory, undertaking primary data collection, understanding context, paying attention to
51 future implementation in the real world, and designing and refining an intervention using iterative
52 cycles of development with stakeholder input throughout” (6). This manuscript details the purpose,
53 guiding principles, and stakeholder involvement in the development of this innovative resource,
54 highlighting its potential to transform osteoporosis care on a global scale.
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2. Establishment of working team and guidance

2.1. Project team

The development of the “Build Better Bones” website required the collaboration of a multidisciplinary team to ensure that the platform met the diverse needs of its intended audience. The project was led by a core team from the Rehabilitation Working Group (SS, DP, OB) and was supported by International Osteoporosis Foundation (IOF) communications team members with a focus on knowledge mobilization. Members of the communications team served as key stakeholders responsible for ensuring the platform's global dissemination and wide reach. Their expertise in outreach and engagement played a central role in positioning the website as an essential tool for people with osteoporosis and their care partners.

The technical aspects of the project were managed by communications and web design experts from Humacom, LLC. and Watkins Media, LLC. This team contributed to the architecture, programming, graphic design and overall visual appeal of the site. Their work included reviewing available templates to adapt them to video requirements, designing user-friendly web pages, and collaborating with illustrators to refine the clarity and accuracy of exercise animations. This collaborative process ensured the development of a cohesive, accessible, user-friendly and visually appealing platform.

2.2. Organizational frameworks

For the “Built Better Bones” platform, the project team utilized the Capability, Opportunity, Motivation – Behavior (COM-B) model of behavior change to guide its development (7). COM-B is an individual level theory of behavior change that suggests people need to have the capability, opportunity, and motivation to change. Capability related to an individual’s psychology and physical capacity to undergo change that is affected by factors such as knowledge and skills. Motivation relates to the processes that energize and direct behavior including goals, habits, emotional response, and analytical decision-making. Opportunity is defined as the factors that lie outside the individual that make the behavior possible or prompt it (7). The “Build Better Bones” website focused on supporting knowledge and skills related to exercise behavior, nutrition, and home safety as a feature of fracture prevention. Understanding the potential for an osteoporosis education, nutrition, and exercise focused website to serve more than the individual, we were also guided by the socioecological model to consider the potential audiences for the content of the website and its future uses (8). This supported the inclusion of information for caregivers to support this crucial interpersonal relationship in osteoporosis management and planned dialogue with members of the Rehabilitation Working Group regarding the potential to use the platform as a tool for clinicians to support patients.

2.3. Initial design constraints

To effectively address the needs of a global audience, several strategic decisions were made in the early stages of the project:

- Defining the targeted behavioral changes: We sought to promote optimal nutrition, regular performance of exercises that improve strength and balance, and promote adoption of home safety measures. These interventions reduce falls and fracture risk.

- Defining the audience: The primary audience for the website is people living with osteoporosis and their care partners. The starting point for exercise selection was based on the Rehabilitation working group (RWG) publication on post fracture rehabilitation management (1). The platform also aimed to support healthcare providers by providing resources that could be recommended to patients. Rehabilitation principles are guided by the Physical Stress Theory and the stresses required to build strength (9); educational topics respect contemporary understanding of pain (10).
- Multilingual and inclusive design: Recognizing the need to serve a global audience, the IOF prioritized the translation of the site into multiple languages. This decision shaped the design choices, with animation favored over video and written text favored over audio for the short term. There is some evidence that voice over animation improves recall in low health literacy patients (11). These decisions facilitate easy translation and representation across different ethnicities. Though we were sensitive to the potential for the perception of animation to be perceived as childish or minimizing the importance of the content. Initial image content was sourced online later complemented by customized images in order to comply with resource constraints.

2.4. Plans for stakeholder input

At the outset of website planning, we discussed the website idea with representatives from Global Healthy Living Foundation and the Bone Health and Osteoporosis Foundation. We requested and received support from Global Healthy Living Foundation, the Bone Health and Osteoporosis Foundation, Osteoporosis Canada, and the Royal Osteoporosis Society to connect with members of their organizations to participate in feedback sessions.

3. Preliminary website development

The development of the preliminary “Build Better Bones” website was guided by input from experts, clinicians and patients through a series of interviews. The purpose of these discussions was to identify the types of information and resources needed to effectively manage and prevent osteoporosis. Feedback highlighted three key areas for inclusion: exercise, diet and home safety. These elements address the critical components of osteoporosis care and focus on empowering individuals to take an active role in maintaining their bone health and preventing fractures.

3.1. Exercise selection and animations

The exercise component presented unique challenges in content selection due to its potential for both benefit and harm. While exercise can improve strength, balance and overall function, inappropriate selection may either fail to provide sufficient benefit or, worse, increase the risk of fracture, which is associated with significant morbidity and mortality. The proliferation of exercise videos, applications, and software for personal health and wellbeing or to support physiotherapy treatment illustrate another issue, the site could be populated with thousands of exercises which could potentially lead to confusion or physical harm if a person attempts to perform an exercise that is beyond their capability (9).

We wished to identify physiotherapist-preferred exercises for different clinical presentations from among a sub-set of exercises described in the literature. This required the team to 1) identify a range of exercises and 2) identify meaningful characteristics on which to create vignettes.

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4 A comprehensive literature review identified 34 common exercises recommended to treat
5 osteoporosis or post hip fracture (1, 12-14). We planned to further narrow the 34 common exercises
6 to a core set of exercises to decrease the burden for the graphic design team and minimize the
7 experience of choice overload for users (15). We understood that it was naïve to ask exercise
8 prescribers for an exercise preference apart from providing basic case information because optimal
9 exercise selection should be based on an individual's functional capacity. Optimal exercise
10 selection meets a person at a point of functional challenge (9).
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13 14 **3.2. Exercise interviews**

15 We identified the need to create clinical vignettes to provide a robust presentation of meaningful
16 patient information to exercise prescribers (16). We used best practice recommendations for
17 patient vignettes development (17). We began with interviews of exercise prescribers (n=6) who
18 had experience in treating older adults with osteoporosis. We asked providers about the type of
19 information they find meaningful when choosing between exercises for a patient or client. To
20 reflect the nature of information that could be easily ascertained through a website, we asked
21 exercise prescribers to limit themselves to the information that could be obtained through clinical
22 observation or direct patient questioning. The interviews were informed by the notion of intrinsic
23 capacity for management of older adults and how it is measured (18). Interviews and vignette
24 construction was conducted by SB and DP. We asked providers what would influence exercise
25 prescription using the following semi-structured prompts:
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- 29 - Observation: What movements or physical presentations suggest a patient's suitability for
30 certain exercises?
- 31 - Patient self-report: Which complaints or concerns expressed by patients influence exercise
32 recommendations?
- 33 - Once vignette attributes were identified we asked about the most meaningful levels of a
34 feature. For example, if strength is an important feature for exercise prescription, how is
35 strength observed, assuming one cannot perform an explicit strength measure? What
36 categories of this observed strength are meaningful to guide exercise selection? For
37 example, the sit-stand activity is used as a performance-based outcome measure that
38 reflects the strength attribute (19) and so it is not surprising that respondents noted
39 variations of this functional task as a signal for functional strength.
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44 An initial attribute list to support vignette creation developed including: balance, functional
45 impairment (muscle strength and coordinated walking), pain, fear of falling.
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4 **3.3. Vignette Attribute testing**

5 Primary vignette attributes and levels were discussed in exercise prescriber interviews with
6 application to hypothetical patients. When discussing attribute levels of balance, prescribers
7 highlighted the difference between static balance and dynamic balance with respect to exercise
8 prescription.
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11 Pain and fear of falling were not tied directly to specific exercise selection, but to exercise-based
12 problem-solving. If a standing march exercise appropriately challenges a person’s dynamic
13 balance, but the person expresses fear of falling an exercise prescriber could choose to change to
14 a less challenging exercise, alter the exercise to decrease the challenge or encourage that the
15 exercise be performed in a different environment or with enhanced safety features. Comments such
16 as, “Have the person do this exercise at a kitchen counter with a chair close by”, “Have a person
17 stand near a handrail”, or “Have a person hold onto the back of a sturdy dining chair” were common
18 environmental adjustments to provide additional stability.
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22 Pain is defined as “an unpleasant sensory and emotional experience associated with, or resembling
23 that associated with, actual or potential tissue damage” (10). Constant versus intermittent pain are
24 meaningful constructs in musculoskeletal disorders of aging and were addressed by respondents
25 as meaningful with exercise selection. With muscle soreness some patients will avoid exercise
26 thinking it to cause harm because muscles are sore and there is corresponding muscle-related
27 stiffness. The difference between a sharp pain that represents potential damage of a bone and
28 muscle ache and stiffness following exercise was important and requires further patient education.
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32 Both examples of exercise-based problem solving were included within the knowledge base of the
33 website and were removed from the attributes for exercise prescription for case development as it
34 is not always necessary to change an exercise completely. This reduced the number of vignettes
35 developed to an amount that would not be cognitively overwhelming to respondents in compliance
36 with guidelines (17).
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Table 1 Final Vignette Attributes to Guide Exercise Recommendations

Attribute	Levels	Vignette descriptions
Static balance	No impairment	Is able to reach forward and well outside her base of support without external assistance when cooking.
	Impairment	Requires the support of the counter or another person when washing hands if he doesn't keep a wide stance.
Dynamic Balance	No impairment	Is capable of completely turning around to grab ingredients on the counter behind her as she's cooking without grabbing on to her cane or the counter for stability.
	Impairment	Is unable to turn around to look in the mirror without shuffling and grabbing on to his walker, wall, or dresser.
Functional level	High	Is able to walk around his home without an aid and is capable of sitting in and standing up from his chair without using his hands.
	Moderate	Uses a cane to walk around his home and is able to perform most of his normal daily activities without caregiver assistance. He does, however, struggle midway into attempting to sit down in a chair and requires the use of the chair arms to smoothly sit down. He also relies on his cane and the railing for the strength to climb.
	Low	Uses his walker to navigate his home and relies on moderate effort from his caregiver to assist in different daily activities, such as getting out of a chair and toileting.

There can be instances when attribute combinations are deemed impossible or highly improbable. Interviewed clinicians felt vignettes without dynamic balance impairment were unlikely to have deficits with static balance as static balance is foundational to dynamic balance. Likewise, vignettes that were labeled as having a high functional level were unlikely to have static balance impairments (as described by the vignettes). Improbable scenarios were excluded from the final group of vignettes.

Patient vignettes attempted to capture meaningful clinical features for guiding exercise prescription across a range of functional abilities, from low to high, using a combination of abilities across the attributes of 'static balance', 'dynamic balance', 'functional level'. Eight (8) vignettes were created and pilot-tested among 5 physiotherapists affiliated with the Department of Physical Therapy at Marquette University. Figure 1 is Vignette #8. For each vignette participants were asked to "Select the top three (3) to five (5) most beneficial exercises to perform at home from the list below." From among the list of 34 exercises per vignettes, the chair sit/stand, step-up/stair climb, squat with wall support, outward leg raise (hip abduction), inward leg raise (hip adduction), back leg raise (hip extension), standing march (hip and knee flexion), standing heel raises/toe raises (ankle plantar flexion/dorsiflexion), and single leg stand exercises were commonly used and served as our starting point to work with members of the graphic design team.

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4 **Case 8: Mr. Martin**

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6 • Is 4 months post surgical stabilization for an osteoporotic hip fracture.
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9 • Is able to walk around his home without an aid and is capable of sitting in and standing up
10 from his chair without using his arms.
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12 • Is able to reach forward and well outside his base of support without external assistance
13 when cooking.
14
15 • Is capable of completely turning around to grab ingredients on the counter behind him as he's
16 cooking without grabbing on to his cane or the counter for stability.
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18 *Figure 1 Example Vignette*

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20 **3.4. Exercise Animation and review**

21 The project team's graphic designer created the first draft of animated videos. Team meetings
22 included review of exercises with the programming design team and clinical leadership team (DP,
23 OB, SS). These meetings included demonstration of exercises and critique of exercises for proper
24 form. This followed an iterative process as does much of Agile development.
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27 **3.5. Exercise knowledge base**

28 The Build Better Bones knowledge base is an area of the site that provides expert insight into
29 common experiences with exercise. The title and content theme of topics are listed in Table 2
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32 *Table 2 Knowledge Base Topics*

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Title	Content theme
Exercise Disclaimer	This site is informative and does not replace the advice of a health professional.
Exercising Safety – listening to your body	Common sensations with exercise, Signs of health conditions that may require medical attention.
Making movement	People complete tasks with a wide range of musculoskeletal functions. Readers are provided with examples of how movement can be interpreted to reveal muscle function that may be improved upon with focused exercise training.
How to exercise – start low and go slow	This section includes why it makes sense to start low and go slow if you are not a regular exerciser. Examples of starting low through partial movements and progressing to deeper full range movements.
Muscle soreness 'pain' versus sharp pain	This section acknowledges that many people feel pain (soreness) with exercise and how it is different from pain that may be a sign of harm. It also has tips for decreasing joint soreness.
Importance of warmups	This section discusses preparing one's body for exercise.
Spine sparing strategies	This section discusses ways for people to protect their spine if they are vulnerable to spinal fracture.
When to increase exercise difficulty	This section provides guidance on progressing exercise.

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54 **3.6. Nutrition**

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57 Nutrition is a cornerstone of osteoporosis management, and the website addresses this by providing
58 evidence-based guidance in an interactive food basket with topics for users to explore and
59 download content in 7 languages.
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Two main components have been included based on literature reviews and stakeholder feedback:

- Practical tips: Guidance to promote healthy eating and support informed food choices, emphasizing the importance of calcium, protein, and vitamin D in maintaining bone health and reducing fracture risk.
- Calcium content: A comprehensive list of calcium-rich foods to help users incorporate this essential nutrient into their diet. This information is available in imperial and metric units.
- Nutritional Disorders and Supplementation: Information is provided on conditions that impact nutritional status and the role of vitamin supplementation in bone health.
- Healthy body weight calculator – allows users to input their age, height, and bodyweight to calculate their osteoporosis risk and make informed lifestyle adjustments.

3.7. Home Safety

Home safety modification is a commonly recommended population-based intervention for fall and fracture prevention (20). Input from patients and professionals highlighted the need to provide practical advice on how to minimize the risk of falls in the home environment. To address this, the website includes an interactive illustrated house feature that highlights potential hazards in various rooms.

- A guide to identifying and addressing common hazards in the home, such as loose carpets, poor lighting, or cluttered walkways.
- Simple, practical solutions to create a safer home for people at risk of falls.

By addressing these hazards, the website aims to empower individuals to proactively protect themselves and their loved ones, reducing the likelihood of falls and their associated consequences.

3.8. Caregivers

Formal and informal care providers are crucial support for most people with osteoporosis post fragility fracture (21, 22). Caregivers have needs for understanding their unique role in a person’s recovery and planning for their increased exposure to health risk (23). Recommendations for comprehensive fracture rehabilitation is that caregivers receive education. This section of the website addresses seven essential elements related to the caregiving role. Table 3 highlights topics and topic themes for Caregiver-focused content on the website.

Table 3 Build Better Bones Caregiver Content

Topic	Topic theme
Know Your Health Specialist	Evaluation measures and treatments
Advocate for the Patient	Preparing for interaction with medical professionals
Fall and Fracture Prevention	Address home safety and risks with common chores
Good nutrition	In-home meal prep using nutrition tab content
Lifestyle assistance	Lifestyle behaviors related to preventing bone loss and building bone and muscle strength
Care following Breaks or Procedures	Osteoporotic patients’ fall protocol
Care for yourself	Self-care is needed to care for others

4. Qualitative input to the website

The design and content of the Build Better Bones website was refined through extensive qualitative feedback from a range of stakeholders to ensure the platform's usability, relevance and inclusivity. This section describes the input gathered through interviews and discussions that played a critical role in shaping the features and functionality of the website.

4.1. Stakeholder input

Between January and March 2022, a combination of interviews and surveys were conducted with 24 stakeholders from the United States, the United Kingdom and Canada. Participants either self-reported having osteoporosis or caring for someone with osteoporosis or were affiliated with organizations such as the Global Healthy Living Foundation, the Bone Health and Osteoporosis Foundation, the Canadian Osteoporosis Patient Network, and the Royal Osteoporosis Society. Stakeholders included patient representatives from respective foundations, clinician input, researcher input, and communication experts. Survey respondents were asked to view the website prior to survey completion, interviewees were guided through the website, tab by tab, and asked to provide real-time feedback by speaking their thoughts aloud. Interviews were conducted and thematically analyzed by MS, SS. Feedback categories are summarized below and Table 4 addresses topics that were raised by stakeholders and remedies produced by the website development team.

4.1.1. Navigation and accessibility

- Participants identified areas where navigation could be improved, such as increasing the size, location and visibility of buttons and adding breadcrumbs to improve site usability. Suggestions included increasing font size for readability, optimizing text spacing and integrating a search bar, library, and interactive web forum/chat. While patients appreciated the accordion-style presentation of information, some recommended replacing "+" symbols with clearer prompts such as "expand" or "read more". In addition, it was suggested that links at the top of pages could be made to resemble buttons for better visibility. White text on a light blue background was identified as difficult to read.

4.1.2. Content framing and communication style

- Stakeholders emphasized the need to balance the seriousness and urgency of osteoporosis with messages of compassion, hope, self-control, and motivation. It was suggested that the platform should include emotionally engaging content such as quotes, statistics, and personal stories to combine factual information with relatable narratives. Such changes were recommended to make the site more appealing to younger users, who may not be aware of the risks of osteoporosis, as well as older users with more immediate needs.

4.1.3. Feedback on specific sections

- Exercise: Stakeholders highlighted the importance of balancing safety, enjoyment, and clear information. They recommended that exercises should be demonstrated bilaterally (e.g., for both legs) and emphasized the need for communication with medical teams for exercise clearance. Suggestions included breaking movements

down into relatable functional activities, such as golf swings or ballet exercises, and adding content on the importance of weight bearing, guidance on fracture location, good posture, and optimal bending. Some stakeholders wished for a greater variety of ages on the site, suggesting the need for younger images of exercising characters.

- Nutrition: Suggestions for future updates included providing recipes, cooking demonstrations and dietary modifications for special needs (e.g., vegan, vegetarian).
- Home safety: Stakeholders recommended including overlooked hazards and strategies to improve safety during activities of daily living (ADLs) and instrumental ADLs (I-ADLs).

4.1.4. General recommendations

- Use inclusive language such as "living with osteoporosis" to avoid labelling all users as patients.
- Include more information about medications, such as antiresorptive and anabolic treatments, and their side effects, as well as non-pharmacological alternatives, such as vibration plates.
- Address the stigma of male osteoporosis ("old lady's disease") to engage more men.

Table 4 Stakeholder Input on Website and Remedy

	Critique	Remedy
Readability and language	Text with low contrast impairs readability, text was too small and spacing between letters were too narrow.	Changed low contrast text to background to high contrast. Increased font size and spacing between letters.
	Minimize the use of the word 'patients' because not all people using the site will be patients.	The word 'patient' was restricted to portions of the site dedicated to the patient or caregiver experience.
Navigation	Navigation was impaired because users were required to scroll to the top of the page to use the navigate bar.	A feature was added where the navigation bar followed the user as they scrolled down the page.
	replacing "+" symbols with clearer prompts such as "expand" or "read more" with expandable material	The prompt to READ MORE was added to the knowledge base.
	Links at the top of pages could be made to resemble buttons for better visibility.	Links at the top of the page were changed to include an image that changes color and shape when the cursor moves over it.
Images	Stock illustrations of older adults were unflattering and appeared to be caricatures of older adults.	Illustrations of older adults were replaced with ones that were more positive and empowering.
	Images only included older adults and not broader age range of people who are affected by osteoporosis.	Images were changed to include middle-aged adults.
Website scope and safety	Be clear about safety concerns and statements related to the site's limitations.	Disclaimers to seek physician or qualified health provider advice about medical diagnoses. Website information does not replace medical advice.

5. Website launch

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4 The official launch of the Build Better Bones website (www.buildbetterbones.org) took place at
5 the World Congress on Osteoporosis, Osteoarthritis and Musculoskeletal Diseases (WCO-IOF-
6 ESCEO) in Barcelona in April 2023. This high-profile event provided a global platform to launch
7 the website to a diverse audience of healthcare professionals, researchers, and patient advocates.
8 The congress was an ideal venue to showcase the potential of the platform to address key
9 challenges in osteoporosis care and promote self-management strategies. To maximize
10 accessibility and reach a broad international audience, the website was initially launched in five
11 languages (English, Spanish, French, Portuguese, and Russian) covering 60% of the countries.
12 This multilingual approach reflects the International Osteoporosis Foundation's commitment to
13 serving a global community and ensuring that people in different regions have access to vital
14 information and resources tailored to their needs. Screenshots of select English language webpages
15 of the buildbetterbones.org website are available in the Appendix.
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20 **5.1. Potential to transform on a global scale**

21 Following the launch of the "Build Better Bones" platform, the IOF performed a targeted social
22 medial campaign the full details of which are beyond the scope of this paper. In brief, the
23 campaign ran between October 20 and November 13, 2023, where three social media posts were
24 disseminated in six countries (Mexico, Spain, Brazil, Portugal, France and Belgium) across
25 multiple social media platforms. The posts reached 1,000,000 people over 60 years old and
26 attracted 30,000 site visits within a three-week period.
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30 **6. Discussion and future steps**

31 **6.1. Key Insights and implications**

32 The development and launch of the Build Better Bones website addresses a critical need for
33 centralized, accessible resources in osteoporosis management. The integration of diverse
34 stakeholder feedback, evidence-based recommendations and inclusive design principles has
35 resulted in a platform that serves both people living with osteoporosis and their care providers. By
36 focusing on key areas such as exercise, nutrition and home safety, the site empowers users to
37 engage in self-management practices that are critical to maintaining bone health and preventing
38 fractures.
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43 The agile development process and stakeholder involvement highlighted the importance of
44 iterative design in creating a user-centered resource. The qualitative feedback received during the
45 development of the site not only improved navigation and usability, but also helped refine the tone
46 and framing of the content to ensure it resonated with different audiences. These insights are
47 valuable for future digital health initiatives targeting similar chronic conditions.
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50 **6.2. Challenges Encountered**

51 Despite its success, the project faced several challenges. Balancing the need for simplicity and
52 scalability with the complexity of tailoring content to different functional and cultural needs
53 required continuous refinement. For example, ensuring that exercise recommendations were safe
54 yet effective required careful consideration of potential risks, which was addressed through expert
55 consultation and the development of vignettes. Similarly, designing visual elements that were both
56 culturally inclusive and acceptable to older adults required modifications to initial concepts based
57 on feedback.
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6.3. Future Enhancements

Several steps could further increase the impact and reach of the site including expanding the range of exercises to people of different levels of ability, expanding content, coordinating with clinical providers, and translating to new languages.

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6.3.1. Expanding the content

14 Stakeholders felt that a broader range of exercises are needed to reflect the range of people who
15 benefit from osteoporosis-related self-management. Our initial exercise selection was for cases
16 that were four months post hip fracture with varying levels of function. We appropriately received
17 feedback from stakeholders saying that the exercises may be too high level for some to perform
18 independently and too low level for others. We decided on this as our starting point because post
19 hip fracture many people will be in supervised rehabilitation programs for between three- and six-
20 months post fracture. We did not intend them to be in competition with exercise software used by
21 rehabilitation professionals during ongoing treatment but envisioned that it could be a tool that
22 they gravitate toward as they plan for discharge. We plan to broaden exercises to expand towards
23 both ends of functional capacity not covered by our site, but we plan to do so being careful not to
24 overwhelm people with too many exercise options. We are sensitive to concerns about decision
25 fatigue (24). To provide a few appropriate exercise options we need to develop interactive tools to
26 support individualized exercise recommendations another suggested recommendation. Other
27 suggested areas of content development include new nutrition resources such as recipes, cooking
28 demonstrations and tailored advice for specific dietary needs; expanded coverage of home safety
29 hazards with additional fall prevention tips for different living environments such the outdoors;
30 expanding the caregivers section with instruction in how to meet the physical demands of
31 caregiving while preventing injury, such as learning how to support the person with osteoporosis
32 as they transfer positions (e.g., moving from lying to sitting position using spine sparing
33 strategies).

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6.3.2. Reaching out to new populations

40 Stakeholders showed high interest about the multilingual support and possible expansion of the
41 number of languages available to increase accessibility for underserved populations. Additional
42 outreach to specific groups can include those traditionally under-served such as men with
43 osteoporosis, to address stigma and encourage wider use of the platform. Expansion of the site can
44 include exercises for those who are less physically able and for those seeking higher impact
45 options. Additionally, it was suggested we work with healthcare providers to encourage adoption
46 of the website as a recommended resource for newly diagnosed patients and their families.

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6.3.3. Research and Evaluation

50 Ongoing evaluation is essential to ensure that the site meets the needs of its users and remains
51 evidence based. Future research initiatives may include:

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- Conducting usability studies to assess how well the site supports user engagement and self-management. Assessment of the site can follow a broad range of outcome from access and understanding to behavior change through ongoing use.
 - Conducting an international survey to assess the perception, usability, and interest in the website among healthcare providers.

- Co-designing an expansion of content such as educational materials with children and young adults to raise awareness of osteoporosis. These materials will emphasize the importance of achieving peak bone mass and adopting lifelong health behaviors to minimize bone loss.

6.4. Conclusion

The "Build Better Bones" website represents a significant step forward in addressing the global challenge of osteoporosis management. By combining evidence-based content with user-centered design, the platform offers a scalable, adaptable, and impactful solution. Continued refinement, expansion, and evaluation will ensure its sustained relevance and effectiveness, contributing to improved quality of life for individuals living with osteoporosis worldwide.

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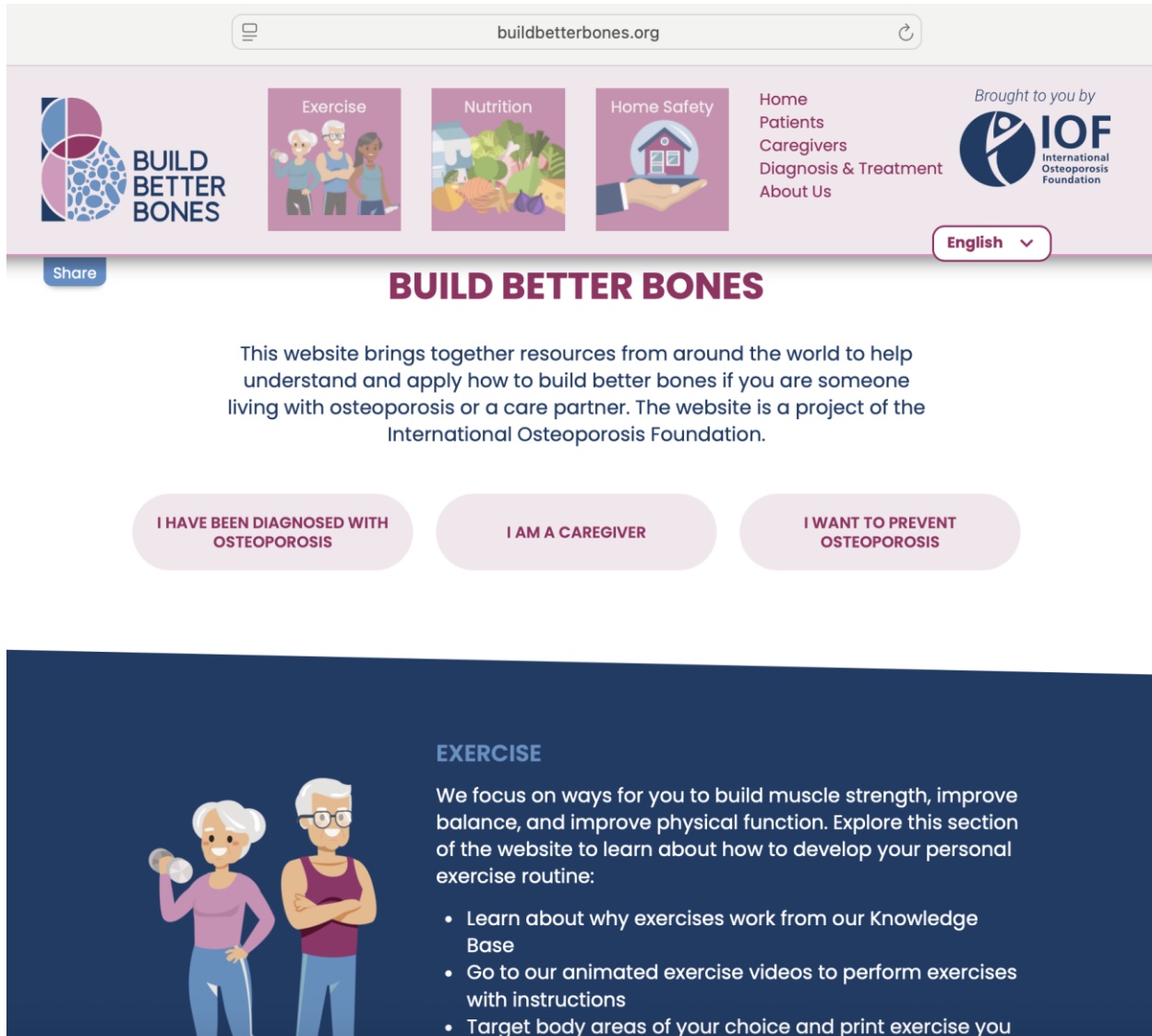
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Appendix: www.buildbetterbones.org screen shots of select pages

Home page – The main page of the buildbetterbones.org site allows navigation to all parts of the website where users can access exercise, nutrition, home safety content. There is also direct access to content specific to people with osteoporosis, those at risk for osteoporosis or for caregivers who support people with osteoporosis.



The screenshot shows the homepage of buildbetterbones.org. The browser address bar displays the website URL. The header features the "BUILD BETTER BONES" logo on the left, a navigation menu with "Exercise", "Nutrition", and "Home Safety" categories, and a list of links: "Home", "Patients", "Caregivers", "Diagnosis & Treatment", and "About Us". On the right, it says "Brought to you by IOF International Osteoporosis Foundation" with the IOF logo. A language dropdown menu is set to "English". Below the header, a "Share" button is visible. The main heading is "BUILD BETTER BONES". A paragraph states: "This website brings together resources from around the world to help understand and apply how to build better bones if you are someone living with osteoporosis or a care partner. The website is a project of the International Osteoporosis Foundation." Three navigation buttons are present: "I HAVE BEEN DIAGNOSED WITH OSTEOPOROSIS", "I AM A CAREGIVER", and "I WANT TO PREVENT OSTEOPOROSIS". The "EXERCISE" section features an illustration of an elderly woman and man, with the text: "We focus on ways for you to build muscle strength, improve balance, and improve physical function. Explore this section of the website to learn about how to develop your personal exercise routine:" followed by a bulleted list: "Learn about why exercises work from our Knowledge Base", "Go to our animated exercise videos to perform exercises with instructions", and "Target body areas of your choice and print exercise you".

Exercise page – This page includes access to animated videos of exercises to build muscle strength and to add gentle bone loading. Users can access the knowledge base that shares insights from experts in exercise who work with people who have osteoporosis and those at risk for osteoporosis.



LEARN ABOUT THE BENEFITS OF EXERCISES

Bones – and muscles – are amazing! They respond to the challenges we place on them if done properly. Exercise is an essential ingredient for bone health and improved balance and strength.

A combination of balance exercises, function-based exercises, strengthening exercises, and bone loading exercises will help keep you mobile and help you maintain your independence.



KNOWLEDGE BASE

Muscle soreness 'pain' versus sharp pain

Body pain is defined as the unpleasant physical feeling and emotional experience that comes with damage or potential damage to part of your body. Most of us can think of a time we've experience body pain.

Exercise Safety – listening to your body

We're sure you've heard of the phrase, "no pain, no gain". While hard work pays off, not listening to your body can be harmful. Many muscle injuries are from incorrect training. Below we list signs and symptoms that show you may be training

