Osteoporosis & Aquatic Exercise: New Research, Novel Techniques

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Historically, aquatic exercise has been overlooked in the management of osteoporosis clients due to decreased weightbearing associated with immersion. This, coupled with the staunch belief that positive bone adaptations are due to mechanical loading accomplished exclusively with weight-bearing activities, has led therapists to ignore the benefits of aquatics for those individuals who might profoundly benefit from aquatic interventions. And while, the animal model demonstrates that gravitational loading does enhance bone growth[1], it is difficult to distinguish intrinsic—muscle-generating force that applies mechanical loads to bone---from extrinsic loading—gravity--- in the human subject.[2] This mechanical interaction between muscle and bone which accounts for motion needs to be reviewed, as aquatic exercise can most assuredly provide sufficient load to move bone.

The ability for bone to detect and respond to mechanical loads is a sensitive process orchestrated by specific cells that respond to forces--- stress, strain, shear, pressure, fluid flow, streaming potential and acceleration; these occur with loading.[1] It is this mechanical information that regulates the bone adaptation, maintenance and repair occurring as a consequence of this constantly changing mechanical environment.[1-3] It is of significance to note, also, that bone does not require *an extreme mechanical signal* to elicit adaptive responses as both low-load magnitude with high frequency and very high magnitude strain can enhance bone strength.[1] As noted by Thompson et al,

> "Mechanical loading of bone through normal daily activities or via 'prescribed' loading regiments, represents a means to protecting skeletal integrity... Delivering mechanical stimuli to improve or maintain bone health has numerous advantages such that mechanical signals are native to bone, safe at low intensities, involve the full range of the remodeling cycle, and result in production of lamellar bone."[1]

In addition to the mechanical interaction between muscle contraction that loads bone, there is increased metabolic activity related to contracting muscles that affects bone growth as well.[4] Current research substantiates that contracting muscles actually act as an endocrine organ, making the relationship between muscle and bone far more intricate and not reliant on strictly weight-bearing exercise to accomplish positive effects on bone.[3-4] Muscle contraction influences bone quality and quantity due to a series of highly regulated cellular interactions which are independent of weight-bearing stresses.[1-3] With this in mind, aquatic exercise can and does provide sufficient stimulus both intrinsically and via the crosstalk occurring with contraction, to be considered a viable option to address bone loss associated with osteoporosis.

The paucity of literature that exists regarding aquatic intervention and positive bone growth, is part of the reason for an under appreciation of water therapy in the management osteoporosis. However, to understand why water is so powerful one must first recognize the unique capabilities that the physical properties of water bring to the table. In a population that is at high risk for fracture, the viscosity of water supports upright posture, exponentially decreasing the risk of a fall when attempting balance or other physical activity.[5-6] Strength plus functional improvements coupled with positive effects on bone were noted in studies by Fernandes Moreira and Keiffer respectively, both incorporating high intensity aquatic exercise to accomplish such gains in osteoporotic subjects.[6-7] In the Keiffer study, a point was made specifically that, "…the improvement in bone metabolism and bone mass observed in our study was not a result of impact exercises in the pool, but a consequence of resistive muscle training against

water resistance" [7] thereby substantiating the muscle's impact on bone formation. Regarding posture, a primary physical characteristic impacted by osteoporosis, a study by Chaves Aveiro et al, demonstrated significant improvement in postural control for osteoporotic postmenopausal women after participating in a 12-wk water exercise program.[8] The authors noted that the aquatic intervention was more effective than land-based therapy at improving postural control for the single-limb stance portion.[9] It is notable that for a group of osteoporotic clients, practicing single leg stance is intrinsically safer in water than on land.

Studies that specifically addressed bone metabolism and mass predominantly stress high intensity activity, with small sample sizes and utilized DXA to establish bone mineral density. A 2018 study by Aboarrage Junior et al, using shallow water and jump training, demonstrated improved bone mineral density for both the femur and the lumbar spine.[9.] An 8-month study by Pernambuco et al demonstrated that aquatic aerobic exercise while improving osteoclastin levels, did not improve lumbar and total femur BMD in the postmenopausal client. However, serum osteocalcin as a marker of bone metabolism, was positively affected by water exercise.[11] Additional studies conducted with younger adult subjects likewise found significant effects on both bone mass and bone turnover.[11]

Given the validated benefits aquatic exercise can offer patients with low bone density, it is a viable and possibly safer alternative to land exercise when weight bearing physical activity is not tolerated or safe due to comorbidities often seen in this population. Additionally, an osteoporotic individual at higher risk of fracture, makes balance training safer in water based on both buoyancy's and viscosity's assistance with an upright position. Aquatic interventions are tailored to address balance deficits, ROM and strength deficiencies, postural concerns commonly seen in this population, and can likewise facilitate improvement in one's aerobic status. Thus, is the specificity of the intervention based on goals set at the onset which provides positive results.

The actual intervention must provide sufficient resistance to effect positive change which requires the therapist to focus on workload intensity---using heart rate, use of a pre-set metronomic device or rate of perceived exertion (RPE)---of significant duration both per bout and total session time. Using HIIT, which provides intervals of intense work loads followed by active rest breaks, one can effectively overload muscles to provide extrinsic forces on the bone. Additionally, use of resistive equipment for both upper and lower extremities---- with emphasis on speed and ROM—can increase workout intensities. The key in providing such a workout is to establish a client's baseline of work tolerance in the water, and then to upgrades of intensity in a consistent pattern so the client works at an intensity that will impact bone growth. AS noted in the studies by both Aboarrage Junior and Keiffer, clients were instructed to work at their maximum effort during the exercise bouts.[7,9]

Appropriate utilization of the unique properties of water, can elicit positive effects on bone. The safety, resistance and constant perturbing effects of the water make it a viable medium for balance, strength training, and functional upgrades, but, *if used appropriately*, can also provide significant improvement in bone adaptations. It, therefore, should not be discounted ---and in fact might be considered safer---to treat those diagnosed with osteoporosis since both bone and functional upgrades can be attained safely.

References

1. Bonewald L. Use it or lose it to age: a review of bone and muscle communication. *Bone*. 2019; 120:21-218. DOI: 10.1016/j.bone.2018.11.002.

2. Brotto M. Johnson ML. Endocrine crosstalk between muscle and bone. *Curr Osteoporos Rep.* 2014;12(2):135-141. DOI: 10.1007/s11914-0209-0.
3. Karsenty G. Mera P. Molecular basis of the crosstalk between bone and muscle. *Bone.*2018;115:43-49. DOI:10.1016/j.bone.2017.04.006.
4. Waller B. Ogonowska-Slodownik A, Vitor M et al. Th effect of aquatic exercise on physical functioning in the older adult: a systematic review with meta-analysis. *Age and Ageing.*2016;45:594-602. DOI: 10.1093/ageing/afw102.
5. Turner AJ. Chander H. Knight AC. Fall in geriatric populations and hydrotherapy as an intervention: a brief review. *Geriatrics.*2018;3(71). DOI: 10.3390/geriatrics3040071.
6. Fernandes Moreira LD. Osorio Fronza FCA. dos Santos RN. et al. High-intensity aquatic exercises (HydroOS) improve physical function and reduce falls among postmenopausal women. *Menopause.*2013;20(10):1012-1019. DOI: 10.1097/GME.ObO13e3182850138.
7. Kieffer HS. Lehman MA. Veacock V. et al. The effects of a short-term novel aquatic exercise program on functional strength and performance of older adults. *Int J Exer Sci.*2012;5(4):321-333.
8. Chaves Aveiro M. Arias Avila M. Santos Pereira-Baldon V. et al. Water- versus land-based treatment for postural control in postmenopausal osteoporotic women: a randomized controlled trial. *Climacteric.* 2017. DOI: 10.1080/13697137.2017.1325460.
9. Aboarrage junior AM. Teixeira CLE. dos Santos RN. et al. A high-intensity jump-based aquatic exercise program improves bone mineral density and functional fitness in postmenopausal women. *Rejuvenation Res.* 2018. DOI: 10.1089/rej.2018.2069.
10. Wochna K. Nowak A. Huta-Osiecka A. et al. Bone mineral density and bone turnover markers in postmenopausal women subjected to an aquatic fitness training program. *Int J Environ Res Pub Health.* 2019; 16. DOI: 10,3390/ijerph16142505.
11. Pernambuco CS. Borba-Pinheiro CJ. de Souza Vala RG. et al. Functional autonomy, bone mineral density (BMD) and serum osteocalcin levels in older female participants of an aquatic exercise program (AAG). *Archive of Gerontol Geriatrics.* 2013;56:466-471. DIO:10.1016/j.archger.2012.12012.