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Effects of Long-Term Surfing on Bone Health in Mature-Aged Males

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Low mechanical loading aquatic activities such as swimming and scuba diving have identified decreased bone mineral density (BMD); however, the effects of long-term surfing on bone health remains uninvestigated. This was a cross-sectional observational study with two groups: surfers ($n = 11$) with 40 years surfing experience and age and gender-matched sedentary controls ($n = 10$). Data collected included physical activity questionnaires, biomarkers, BMD, bone mineral content, and body composition. Surfers demonstrated a significantly ($p < .05$) higher mean BMD in the arms (+18.8%), trunk (+26.1%), ribs (+27.2%), spine (+39.5%), and lumbar spine (+22.8%). Surfers also exhibited a significantly ($p < .05$) higher BMC in the arms, trunk, ribs, spine, and pelvis. Surfers also had a significantly higher ($p = .046$) lean muscle mass in their arms (+16.8%). Our results indicate long-term participation in surfing is beneficial to bone health and may be an ideal physical activity for middle-aged aquatic enthusiasts.

Keywords: aquatic exercise, bone mineral density, bone mineral content, surf

Surfing has been a popular recreational aquatic activity in Australia since it was first introduced in the 1950s and 1960s with its popularity growing off the back of

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the Malibu surf board made famous in the 1940s in California. In Australia, it is estimated there are currently over 2.7 million recreational surfers, with approximately one in 10 Australians participating in this aquatic activity and one third of nonsurfers interested in learning to surf (Stark, 2013). Despite the popularity, concern has been raised with regard to the questionable bone-loading challenges of aquatic activities which includes surfing (Becker, 2009).

Bone health is an important factor of aging and it is well recognized that weight-bearing physical activity can have a positive effect on bone health (Warner, Shea, Miller, & Shaw, 2006). The forces applied to bone ultimately affect the balance between osteoclastic (bone breakdown) and osteoblastic (bone formation) activity (Iolascon, Resmini, & Tarantino, 2013). Compressive force loading of the musculoskeletal system during ambulatory movements such as running and squatting exercise results in bone having greater osteoblastic activity opposed to osteoclastic activity and therefore an improved bone strength and mass (Chen, Liu, You, & Simmons, 2010). Conversely, participation in nonweight bearing aquatic activities such as scuba diving and swimming has been shown to be detrimental to bone health (Warner et al., 2006). Hwang, Bae, Hwang, Park, and Kim (2006) reported that the time spent in the water by breath-hold divers is proportional to the reduction in BMD. Pereira Silva et al. (2004) investigated the BMD of professional scuba divers and observed there was a significantly lower BMD in divers ($p < .05$) in both their spine (-3.53%) and hip (-4.80%) compared with age and gender-matched controls. Bellew and Gehrig (2006) investigated female recreational swimmers and reported they had a significantly ($p < .001$) lower BMD than controls and soccer athletes ($p = .001$). Similarly, Taaffe et al. (1995) investigated the BMD in female gymnasts, swimmers and age and gender-matched controls. Gymnasts exhibited the highest BMD in the hip ($1.117\text{g}/\text{cm}^2$, $SD \pm 0.110$), followed by the controls ($0.974\text{g}/\text{cm}^2$, $SD \pm 0.105$). Swimmers demonstrated the lowest BMD in the hip ($0.875\text{g}/\text{cm}^2$, $SD \pm 0.105$), 10.16% lower than the controls ($p = .0001$). The effects of swimming on BMD has also been evaluated in mature-aged (65 years and older) swimmers who competed in the National Senior Olympic Games. Velez et al. (2008) concluded that elderly males who completed only swimming as exercise should participate in moderate impact activities for their skeletal health.

Currently there is a lack of understanding with respect to aquatic activities on BMD as evidenced by a recent systematic review (SR) (Gómez-Bruton, Gonzalez-Aguero, Gomez-Cabello, Casajus, & Vicente-Rodriguez, 2013) which reported mixed findings. A total of four studies completed on adults 40 years of age and older who were swimmers were found to have a higher upper limb BMD compared with the control groups. These studies however did not take into account other physical activities or calcium intake, all variables the authors recognized as affecting BMD. The same SR also reported four studies which investigated older recreational swimmers, which found a lower mean BMD values in the legs, lumbar spine, and hip as compared with controls. These findings suggest benefits in BMD may be associated to the upper limbs only within swimming subgroups.

Surfing has also been shown to be a low impact activity with very low ground reaction forces while sitting and paddling ($0.73\text{--}0.76\text{ N}/\text{kg}$) (Loveless, 2014). The pop up phase, which involves going from the seated position straddling the board and paddling to standing has been shown to be associated with a higher ground reaction force ($9.56 \pm 1.25\text{ N}/\text{kg}$) (Eurich et al., 2010). However, time and motion

analysis of recreational surfers conducted by Watsford, Murphy, & Coutts (2006) reported a 60 min recreational surfing session involved 34% sitting, 55% slow-moderate paddling, 8% fast paddling, and only 3% wave riding. Therefore, the total stimulus of high ground reaction forces on bone is limited to only 1.8 min (i.e., 3.0%) while surfing, hence the positive bone remodeling potential of surfing would be significantly low. Secomb, Sheppard, and Dascombe (2014) recently supported these findings and reported surfers were riding waves only 2.5% of a 2 hr surfing session.

Given surfers spend the majority of the time (97%) in a reduced quasi-weight bearing environment we suspect this may result in increased osteoclastic activity. Without adequate stimulus, osteoclastic activity will exceed osteoblastic activity and result in decreased BMD and subsequently an increased risk of fracture (Duan, Duboeuf, Munoz, Delmas, & Seeman, 2006).

Given the lack of research investigating bone health in mature-aged surfers, the primary aim of this research project was to assess the bone mineral density and bone mineral content in mature-aged male surfers and their age and gender-matched counterparts. We hypothesized the lack of mechanical loading associated with long-term surfing would result in lower BMD and BMC. A secondary aim was to determine if differences existed in segmental body composition, specifically lean mass between the two groups.

Method

This research used a cross-sectional observational study design. Approval to conduct this study was provided by the Bond University Human Research Ethics committee (RO1655).

Data Collection

To investigate the effects of chronic surfing, middle-aged surfers with a minimum of 40 years surfing experience and age and gender-matched sedentary controls for comparison were recruited as participants. To locate potential surfers, local board riding clubs were contacted and informed of the research. Sedentary controls were attained through advertisements at the university and local community cafes. All potential participants were initially screened for smoking status, prescribed medications, or disorders that would affect bone turnover, medical history of osteopaenia or osteoporosis, and previous or current activity that would significantly affect BMD or BMC (employment or recreational). Participants who had or were currently completing any form of resistance or weight training were excluded from participation.

Individuals who passed the initial screening were invited to participate in this study. Upon arrival to the Water Based Research Unit located at the Bond University Institute of Health and Sport, potential participants were provided with an explanatory statement of the research and encouraged to ask any questions. If agreeable to the tests and procedures, they then provided written informed consent. The participants then completed three questionnaires. Two surveys quantified their past bone specific physical activity (pBPAQ) and current bone specific physical activity (cBPAQ) (Weeks & Beck, 2008); the third survey quantified participants

current calcium intake from the Osteoporosis International website (International Osteoporosis Foundation, 2014). Participants were requested to remove their shirt, slacks, shoes, and socks to assess their height on a standard medical balance scale (Seca, 700, Hamburg, Germany); waist circumference was measured using a standard steel metal tape. Participants were then escorted to the bone and body composition laboratory to undergo a dual-energy x-ray absorptiometry (DXA) scan (General Electric, Prodigy Pro, Madison, Wisconsin, USA) for measurement of total body mass, as well as analysis of BMD, BMC, and segmental body composition. A total body scan was selected as this has been shown to provide the identification of osteoporosis at numerous skeletal sites and data on body composition (Melton et al., 2005). All participants were scanned according to Australian Institute of Sport best practice protocols for a total body scan (Nana, Slater, Hopkins, & Burke, 2012). Before conducting the full study, a pilot study was conducted to determine the reliability of data collection and analysis of the DXA scans.

Lastly, all participants were provided with a pathology request to have the biomarkers serum carboxy-terminal collagen crosslinks (CTX, osteoclastic-activity) and serum procollagen type 1 n-terminal propeptide (PINP, osteoblastic-activity) analyzed by a commercial pathology laboratory (Sullivan Nicolaides Pathology, Gold Coast, Queensland). Both CTX and PINP have been shown to be the best biomarkers to determine the current status for bone resorption (bone loss), bone formation, and prediction of fracture (Vasikaran et al., 2011).

Data Analysis

Normality was assessed by investigating kurtosis, skewness, Q-Q plots, as well as the Kolmogorov-Smirnov test with the Lilliefors significance correction. Statistical significance between group differences was determined using independent samples *t* tests. A bivariate Pearson correlation was used to assess relationship between variables, alpha was set a priori at $p < .05$ to determine statistical significance. All statistical analyses were completed using the IBM Statistical Package for the Social Sciences (SPSS, Version 20.0) software program.

Results

A total of 21 mature-aged, nonsmoking males volunteered to participate in this study. Following screening, 11 active surfers with a minimum of 42 years consecutive surfing experience and 10 aged and gender-matched sedentary controls completed all surveys (past physical activity, current physical activity, and calcium intake) and tests (physiological and pathology).

With regard to surf specific demographics, surfers had a mean surfing experience of 49.6 years ($SD \pm 5.2$) and surfed approximately 4 days per week (mean 4.0 d, $SD \pm 1.5$), although some surf participants were surfing up to 7 days each week. With regard to surfing stance, 54% of the surfers had a goofy stance (right foot forward). All surfing participants used longboards which ranged in length from 9–10 ft (2.74–3.05 m).

Table 1 depicts the surfers and control group characteristics. There were no significant differences between the groups demographic characteristics; however, surfers were marginally older (+5.9%), slightly heavier (+12.4%) with a corre-

Table 1 Demographic Characteristics of Surfers and Controls (Mean (\pm SD))

Parameter	Surfers ($n = 11$)	Controls ($n = 10$)	<i>P</i> value
Age (yrs)	63.3 (\pm 4.7)	59.7 (\pm 4.5)	0.091
Weight (kg)	92.9 (\pm 18.9)	82.6 (\pm 16.9)	0.202
Lean mass (kg)	58.09 (\pm 6.59)	53.50 (\pm 6.45)	0.125
Fat mass (kg)	31.47 (\pm 14.78)	25.80 (\pm 10.94)	0.334
Percent fat (%)	33.35 (\pm 9.10)	31.30 (\pm 6.70)	0.571
Waist circumference (cm)	102.18 (\pm 13.90)	93.55 (\pm 13.28)	0.164
pBPAQ score	59.9 (\pm 54.4)	49.7 (\pm 39.9)	0.632
cBPAQ score	1.4 (\pm 3.2)	1.9 (\pm 3.0)	0.657
Calcium intake (% of RDI)	106.5 (\pm 48.6)	100.2 (\pm 49.4)	0.773

sponding lower lean mass (-4.1%), higher fat mass (+21.9%), and larger (+6.1%) waist circumference. There was also no significant difference between the groups past (pBPAQ) or current (cBPAQ) bone specific physical activity. On average, both groups met the daily recommended dietary intake (RDI) requirements for calcium.

Intrarater Reliability

Before conducting the DXA study we used a sample population ($n = 8$) to assess the intrarater reliability with regard to collecting and analyzing BMD, BMC, lean mass, and fat mass. One investigator analyzed all scans. There were no significant differences between the two scans with the absolute intrarater reliability ranging from 0.02% (total BMD) to 1.61% (total fat mass). The intraclass correlation coefficient (ICC) is recognized as the preferred test retest correlation coefficient and was the method used to determine reliability in this study (Lexell & Downham, 2005). A two-way mixed model was used to determine reliability between measure one and measure two within the same session (ICC_{3,1}). With regard to BMD, the ICC was 0.998 (CI 0.991–1.000), BMC ICC was 0.994 (CI 0.973–0.999), lean mass ICC was 0.989 (CI 0.953–0.997), and fat mass ICC was 0.995 (CI 0.976–0.999). All of these values represent excellent reliability according to the recommendations of Fleiss (1986).

Segmental Bone Mineral Density and Bone Mineral Content

There were significant differences identified between the two groups in the upper body and trunk with regard to BMD and BMC. With regard to BMD, surfers were found to have a significantly ($p < .05$) higher BMD in the arms (+12.8%), trunk (+19.6%), ribs (+16.5%), spine (+21.2%), and lumbar spine (L₁ to L₄, +21.2%). A trend of a higher BMD in the surfing group with regard to the legs (+7.0%) was also identified, though this was nonsignificant ($p = .157$). A correlation between total body BMD and total lean mass identified a significant, positive association

($p = .008$, $r = .561$); therefore, the significant differences observed in overall BMD was attributed, in part, to an increased lean mass in the surfers. There was also a significant ($p = .001$), positive association ($r = .687$) between total arms BMD and lean mass.

With regard to BMC, we also identified a number of body segments where surfers had a significantly ($p < .05$) higher BMC as compared with sedentary controls. Surfers had a significantly higher BMC in the arms (+18.8%), trunk (+26.1%), ribs (+27.2%), spine (+39.5%), and pelvis (+24.1%); there was, however, a non-significant trend for a higher BMC in the legs (+6.9%). Segmental BMD and BMC results between groups are depicted in Table 2.

Segmental Body Composition

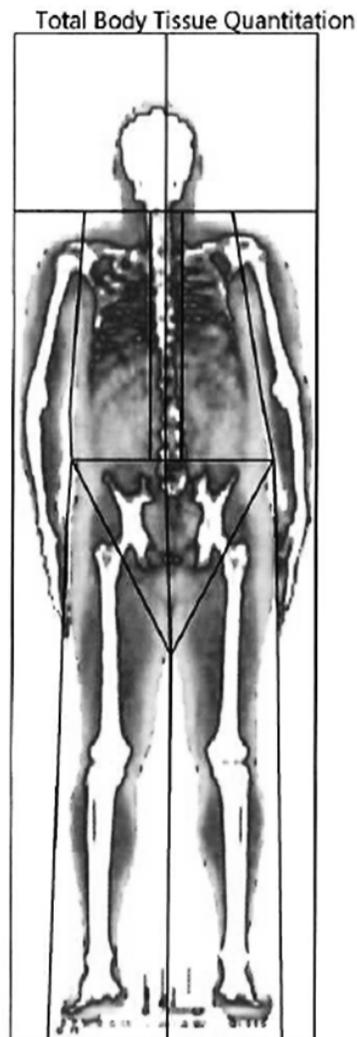
The DXA total body scan also identified a significant difference between the groups with regard to muscle mass (Table 3). Figure 1 illustrates the output screen with the cut lines (black) visible which allows accurate differentiation of the various body segments. Surfers, as a group, displayed a significantly ($p < .05$) higher absolute lean mass in their arms (+16.8%) as compared with sedentary controls. However, when lean mass was compared as a percentage of total body mass, there was no difference between the groups ($p = .387$). In addition, there was no significant

Table 2 Segmental Bone Mineral Density and Bone Mineral Content of Surfers and Controls. Results Expressed as Mean (\pm SD)

Parameter	Surfers ($n = 11$)	Controls ($n = 10$)	<i>P</i> value
Bone Mineral Density			
Total body BMD (g/cm ²)	1.375 (\pm 0.152)	1.274 (\pm 0.104)	0.096
Arms (g/cm ²)	1.231 (\pm 0.100)	1.091 (\pm 0.862)	0.003
Legs (g/cm ²)	1.367 (\pm 0.165)	1.278 (\pm 0.099)	0.157
Trunk (g/cm ²)	1.212 (\pm 0.204)	1.013 (\pm 0.162)	0.024
Ribs (g/cm ²)	1.011 (\pm 0.136)	0.868 (\pm 0.111)	0.017
Spine (g/cm ²)	1.471 (\pm 0.225)	1.204 (\pm 0.279)	0.026
Lumbar spine (L ₁ to L ₄ , g/cm ²)	1.468 (\pm 0.240)	1.195 (\pm 0.240)	0.023
Pelvis (g/cm ²)	1.170 (\pm 0.189)	1.063 (\pm 0.149)	0.172
Bone Mineral Content			
Arms (g)	522.45 (\pm 77.295)	439.80 (\pm 53.991)	0.011
Legs (g)	1120.73 (\pm 205.613)	1113.20 (\pm 1116.057)	0.162
Trunk (g)	1055.64 (\pm 213.813)	837.30 (\pm 175.707)	0.020
Ribs (g)	348.55 (\pm 72.697)	274.10 (\pm 61.557)	0.021
Spine (g)	301.82 (\pm 78.999)	216.30 (\pm 75.554)	0.020
Lumbar spine (L ₁ to L ₄ , g)	90.82 (\pm 25.58)	74.30 (\pm 31.75)	.203
Pelvis (g)	406.82 (\pm 84.936)	327.90 (\pm 62.115)	.026

Table 3 Segmental Body Composition of Surfers and Controls. Results Expressed as Mean (\pm SD)

Parameter	Surfers ($n = 10$)	Controls ($n = 10$)	<i>P</i> value
Arms lean mass (g)	7814.8 (\pm 1220.9)	6690.0 (\pm 1192.7)	0.046
Arms fat mass (g)	3924.6 (\pm 2067.2)	2696.6 (\pm 868.0)	0.098
Legs lean mass (g)	18955.7 (\pm 2985.8)	17456.8 (\pm 2118.1)	0.205
Legs fat mass (g)	8307.9 (\pm 4407.0)	6988.4 (\pm 2050.4)	0.398
Trunk lean mass (g)	26499.6 (\pm 5141.0)	24946.3 (\pm 5395.8)	0.508
Trunk fat mass (g)	17180.8 (\pm 7743.2)	15136.5 (\pm 8164.1)	0.563

**Figure 1** — DXA output image indicating segmental cut lines.

difference between the groups with regard to muscle symmetry (right vs left side) ($p = .848$). There were no other significant differences in segmental body composition between groups.

Bone Turnover Biomarkers

There were no significant differences in the serum blood markers of CTx ($p = .143$) and P1NP ($p = .650$) between surfers and controls. However, we identified surfers had a lower (-21.2%) CTx (mean 0.2318ug/L, $SD \pm 0.076$) when compared with controls (mean 0.2810ug/L, $SD \pm 0.070$) indicating less bone resorption (i.e., breakdown of bone). In addition, surfers had a greater (+6.7%) P1NP (mean 45.46ug/L, $SD \pm 15.90$) compared with controls (mean 42.41ug/L, $SD \pm 0.21$), indicating a higher rate of bone formation. Collectively, these statistically nonsignificant trends are evidence of an advantageous status of overall bone metabolism in the surfers group as compared with sedentary controls.

Discussion

The primary aim of this study was to investigate the BMD, BMC, and segmental body composition in mature-aged male surfers. Stringent screening of participants was used in an attempt to minimize confounding variables such as physical activity, employment, smoking status, and calcium intake on BMD as these have previously been demonstrated to be confounding factors with regard to BMD and BMC (Hollenbach, Barrett-Connor, Edelstein, & Holbrook, 1993; Sanders et al., 2009). Although the rigorous screening minimized confounding effects on BMD and BMC, it resulted in making recruitment of surfers and controls into the study a challenging prospect.

With regard to ensuring an adequate surfing dose upon BMD and BMC, we believe the participants in this study are well representative of mature-aged surfers based upon the mean ages and all surfing participants had over 42 years of consecutive surfing experience and were currently surfing. An increased body mass of surfers over the control group is not surprising as previous aquatic based studies in competitive swimmers found a greater mean body mass in the swimmers than those of aged-matched controls (Walsh et al., 2013). Unfortunately, the authors did not collect data on body fat (Wroblewski, Amati, Smiley, Goodpaster, & Wright, 2011) in this study to allow comparison.

The frequency and duration of activity for the surf participants meets, indeed exceeds the American College of Sports Medicine (ACSM) Guidelines for physical activity (Haskell et al., 2007). The ACSM guidelines recommend a minimum of 30 min of moderate physical activity or exercise 5 days a weeks (or 20 min of vigorous intensity exercise 3 days a week) yet the majority (72%) of the surfers in this study had age and gender specific percent body fat values in the obese category (> 29% fat) whereas the control group was slightly lower with 60% classified as obese. Wroblewski et al. (2011) however reported much lower (15.6–21.12%) percent body fat in older (60–70+ yrs) male master athletes. For comparative purposes to the Australian general population, the Australian Institute of Health and Welfare (2014) recently reported only 19.9% of Australian males aged 65–74 were obese which is significantly lower than the surfing participants in this study.

We recognize that DXA is the current gold standard (Fowke & Matthews, 2010) for determination of body composition however for comparative purposes we also assessed how much the weight of the participants departed from what is considered desirable or recommended for their heights, namely the body mass index (BMI). The average BMI of Australians as reported by Craig, Halavatau, Comino, and Caterson (2001) were lower than that found in the surfers in this study (26.5 kg/m^2 compared with 30 kg/m^2) however comparable to our controls (26.9 kg/m^2). Contextualization to more recent BMI values was conducted via comparative analysis of data reported by the 2011–2012 Australian Bureau of Statistics (Pink, 2013) for Australian adult men in the age groups 55–74 years old, which was deemed most appropriate to compare with our study participants. Of this group of adult Australian males, 79.4% were either overweight ($25.0\text{--}29.9 \text{ kg/m}^2$) or obese ($\geq 30.0 \text{ kg/m}^2$), with 42.9% classified as overweight ($25.0\text{--}29.9 \text{ kg/m}^2$) and 36.4% classified as obese ($\geq 30.0 \text{ kg/m}^2$). This is comparative to the findings of the BMI results for the surfers in the current study. Given the higher percentage of the surfers in the obese classification compared with the Australian national population, the higher incidence of elevated percent fat among the surfers is of concern as it is associated with a number of chronic diseases including type 2 diabetes, cardiovascular disease, hypertension, and certain cancers (Guilbert, 2003). The elevated body fat of our surfing participants suggests surfing may not be an adequate stimulus to maintain a normal percent fat (21.1–25%) and its associated reduced health risks. The elevated mass and elevated body fat of our surfing participants may be attributed to the majority of time surfing attributed to sedentary activity (42–52%) (Secomb et al., 2014; Watsford et al., 2006) or low intensity activity (55%), both of which would be associated with a low caloric expenditure and subsequently contribute to an increased body mass. Commensurate with the elevated percent body fat the surfers also demonstrated an increased waist circumference compared with the control group. An increased waist circumference, independent of body fat, has also been shown to be a risk factor for a number of chronic diseases including type 2 diabetes, high cholesterol, hypertension, and cardiovascular disease (Refshauge, 2012; Tuuri, Loftin, & Oescher, 2002).

To examine the effect of past and current physical activity on bone remodeling the BPAQ tool was used (Weeks & Beck, 2008). The BPAQ was based upon prior research, most noteworthy being the Dolan, Williams, Ainsworth, and Shaw (2006) study of a bone loading questionnaire. The BPAC has previously been used (Bolam et al., 2014; Tuuri et al., 2002) to determine the relationship between physical activity and bone status in healthy middle-aged and older men, Bolam et al. (2014) determined the BPAQ predicted the variance in total hip, femoral neck, and spine BMD. As illustrated in Table 1, there were no significant differences between surfers and controls in both past (pBPAQ) or current (cBPAQ) physical activity. However, a significant limitation to the pBPAQ and cBPAQ is that neither tool took into account surfing as physical activity as there is no ground reaction force data on surfing available. Consequently, this limitation would have underestimated the total forces applied to surfers during their lifetime of surfing as well as current forces they subject themselves to while surfing. Therefore the surfing activity appears to be the only difference in physical activity between the two groups.

To ensure DXA results would be within an acceptable margin of error, we completed an intraexperimenter reliability pilot study before the main study. Intra-

rater reliability involved repeat testing of a limited number ($n = 8$) of participants for data collection and analysis of BMD, BMC, and segmental body composition (lean mass and fat mass). Any differences between the two scans should have derived from repositioning of the participants as well as any error of the scan. The results were not significantly different with a highest absolute total margin of error being +1.6%, which was previously reported by Mattila, Tallroth, Martinen, and Pihlajamaki (2007) and found to be acceptable. Therefore, having demonstrated an acceptable experimenter reliability and very high ICC's lends confidence to our BMD, BMC, and segmental body composition findings in this study.

Contrary to our expectation that surfers would have a lower BMD compared with controls we identified that surfers actually demonstrated a greater BMD in the arms, trunk, ribs, spine, and pelvis as compared with the sedentary controls (Table 2). The development of higher BMD in the surfers was most likely the result from the torque applied to the arms while paddling. Orwoll, Ferar, Oviatt, McClung, and Huntington (1989) previously investigated the BMD of swimmers and found a significantly increased BMD in their wrists as compared with sedentary controls. Orwoll et al. (1989) attributes this increased BMD to the forces applied by the forearm muscles while swimming. As the surfers had a significantly higher lean mass in the arms, the increased BMD may also be a result of the tension developed from the muscle shear force on the bone. The external forces and internal muscular forces have both been theorized to contribute to positive bone remodelling (Ferry et al., 2011; Kohrt, Barry, & Schwartz, 2009). Hwang et al. (2006) investigated the BMD of breath-hold divers and concluded that the repetitive forceful muscular contractions against the resistance of water may have a greater effect on BMD than the absence of weight-bearing activity.

With regard to the spine, lumbar spine (L_1 to L_4) and trunk, we attributed the significantly higher spine BMD (+21.2%, $p = .026$) and lumbar spine BMD (+22.8%, $p = .023$) to surfers spending a significant amount of time (65%) paddling which requires the surfers to maintain an extended isometric posture. Key spinal extensors such as the erector spinae (iliocostalis, longissimus, and spinalis) are crucial in maintaining this isometric extended position. Sinaki, McPhee, Hodgson, Merritt, and Offord (1986) have identified a significant positive correlation between back extensor strength and spine BMD. Halle, Smidt, O'Dwyer, and Lin (1990) also reported a significant correlation ($p < .01$, $r = .67$) between muscle torque and BMD of the spine, they concluded that there is a strong positive relationship between flexor and extensor strength of the spine and BMD. Our current study evaluating surfers isometric extensor strength using the Biering-Sørensen test has revealed surfers (competitive and recreational) have very high endurance times (mean 147.13 s, $SD \pm 42.53$) in comparison with previously published norms (McGill, Melanie, Crosby, & Russell, 2010).

With regard to the significantly higher BMD in the ribs in surfers, we believe this is attributed to compressive forces incurred while paddling and surfing, which accounts for 66% of the total time during a surfing session. We also believe the increased BMD in the pelvis is due to compressive forces in the prolonged prone position while paddling. Although there were no significant differences in the biomarkers P1NP and CTx, we believe the overall bone balance of greater bone formation as opposed to bone loss found in the surfers is advantageous with regard to their ongoing bone health.

Conclusions

This is the first investigation of bone health and segmental body composition in surfers to date. The bone health of mature-aged surfers who exclusively surf for their physical activity was investigated as this cohort would best represent the effects of long-term surfing on BMD and BMC. From this study it was identified that surfing appears to be advantageous with regard to BMD and BMC, however limited to the upper body segments which are most involved while surfing. Furthermore, aquatic activity specific improvements in body composition, specifically in lean mass in the arms, which are heavily involved in paddling while surfing, were also evident. Given the elevated percent fat demonstrated by the surfing participants, mature-aged surfers are recommended to incorporate other modes of aerobic exercise into their physical activity regimen to improve weight management for long-term health benefits. It is also recommended surfers participate in progressive resistance training exercise to improve the BMD of their legs which should subsequently reduce their risk of fracture in later life.

Our findings indicate long-term participation in surfing is beneficial to bone health and therefore contributes to an improved overall health while aging. Future studies which evaluate the serial assessment of BMD and BMC in young, middle-aged, and mature-aged individuals who surf may provide further information on the time course changes in bone health associated with surfing throughout the lifespan.

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References

- Australian Institute of Health and Welfare. (2014). Older Australia at a glance (fourth edition). Retrieved September 8, 2014, from <http://www.aihw.gov.au/publication-detail/?id=6442468045>
- Becker, B.E. (2009). Research needs in aquatics. *International Journal of Aquatic Research and Education*, 3, 4–9.
- Bellew, J.W., & Gehrig, L. (2006). A comparison of bone mineral density in adolescent female swimmers, soccer players, and weight lifters. *Pediatric Physical Therapy*, 18(1), 19–22. PubMed doi:10.1097/01.pcp.0000200952.63544.16
- Bolam, K.A., Beck, B.R., Adlard, K.N., Skinner, T.L., Cormie, P., Galvao, D.A., . . . Taaffe, D.R. (2014). The relationship between BPAQ-derived physical activity and bone density of middle-aged and older men. *Osteoporosis International*. PubMed
- Chen, J-H., Liu, C., You, L., & Simmons, C.A. (2010). Boning up on Wolff's Law: Mechanical regulation of the cells that make and maintain bone. *Journal of Biomechanics*, 43(1), 108–118. PubMed doi:10.1016/j.jbiomech.2009.09.016
- Craig, P., Halavatau, V., Comino, E., & Catterson, I. (2001). Differences in body composition between Tongans and Australians: time to rethink the healthy weight ranges? *International Journal of Obesity and Related Metabolic Disorders*, 25(12), 1806–1814. PubMed doi:10.1038/sj.ijo.0801822

- Dolan, S.H., Williams, D.P., Ainsworth, B.E., & Shaw, J.M. (2006). Development and reproducibility of the bone loading history questionnaire. *Medicine and Science in Sports and Exercise*, 38(6), 1121–1131. PubMed doi:10.1249/01.mss.0000222841.96885.a8
- Duan, Y., Duboeuf, F., Munoz, F., Delmas, P.D., & Seeman, E. (2006). The fracture risk index and bone mineral density as predictors of vertebral structural failure. *Osteoporosis International*, 17(1), 54–60. PubMed doi:10.1007/s00198-005-1893-5
- Eurich, Alea D., Brown, Lee E., Coburn, Jared W., Noffal, Guillermo J., Nguyen, Diamond, Khamoui, Andy V., & Uribe, Brandon P. (2010). Performance differences between sexes in the pop-up phase of surfing. *Journal of strength and conditioning research / National Strength & Conditioning Association*, 24(10), 2821–2825. doi: 10.1519/JSC.0b013e3181f0a77f
- Ferry, B., Duclos, M., Burt, L., Therre, P., Le Gall, F., Jaffre, C., & Courteix, D. (2011). Bone geometry and strength adaptations to physical constraints inherent in different sports: comparison between elite female soccer players and swimmers. *Journal of Bone and Mineral Metabolism*, 29(3), 342–351. PubMed doi:10.1007/s00774-010-0226-8
- Fleiss, J.L. (1986). *The design and analysis of clinical experiments* doi:DOI: 10.1002/9781118032923
- Fowke, J.H., & Matthews, C.E. (2010). PSA and body composition by dual X-ray absorptiometry (DXA) in NHANES. *The Prostate*, 70(2), 120–125. PubMed
- Gómez-Bruton, A., Gonzalez-Aguero, A., Gomez-Cabello, A., Casajus, J.A., & Vicente-Rodriguez, G. (2013). Is bone tissue really affected by swimming? A systematic review. *PLoS ONE*, 8(8), e70119. PubMed doi:10.1371/journal.pone.0070119
- Guilbert, J.J. (2003). The world health report 2002 - reducing risks, promoting healthy life. *Education for Health (Abingdon)*, 16(2), 230. PubMed doi:10.1080/1357628031000116808
- Halle, J.S., Smidt, G.L., O'Dwyer, K.D., & Lin, S.Y. (1990). Relationship between trunk muscle torque and bone mineral content of the lumbar spine and hip in healthy postmenopausal women. *Physical Therapy*, 70(11), 690–699. PubMed
- Haskell, W.L., Lee, I.M., Pate, R.R., Powell, K.E., Blair, S.N., Franklin, B.A., . . . Bauman, A. (2007). Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Medicine and Science in Sports and Exercise*, 39(8), 1423–1434. PubMed doi:10.1249/mss.0b013e3180616b27
- Hollenbach, K.A., Barrett-Connor, E., Edelstein, S.L., & Holbrook, T. (1993). Cigarette smoking and bone mineral density in older men and women. *American Journal of Public Health*, 83(9), 1265–1270. PubMed doi:10.2105/AJPH.83.9.1265
- Hwang, H., Bae, J., Hwang, S., Park, H., & Kim, I. (2006). Effects of breath-hold diving on bone mineral density of women divers. *Joint, Bone, Spine*, 73(4), 419–423. PubMed doi:10.1016/j.jbspin.2005.07.005
- International Osteoporosis Foundation. (2014). Calcium calculator. Retrieved 24 September 2014, from <http://www.iofbonehealth.org/calcium-calculator>
- Iolascon, G., Resmini, G., & Tarantino, U. (2013). Mechanobiology of bone. *Aging Clinical and Experimental Research*, 25(Suppl. 1), S3–S7. PubMed doi:10.1007/s40520-013-0101-2
- Kohrt, W.M., Barry, D.W., & Schwartz, R.S. (2009). Muscle forces or gravity: what predominates mechanical loading on bone? *Medicine and Science in Sports and Exercise*, 41(11), 2050–2055. PubMed doi:10.1249/MSS.0b013e3181a8c717
- Lexell, J.E., & Downham, D.Y. (2005). How to assess the reliability of measurements in rehabilitation. *American Journal of Physical Medicine & Rehabilitation*, 84(9), 719–723. PubMed doi:10.1097/01.phm.0000176452.17771.20
- Loveless, D.J. (2014). Paddling Performance in Recreational and Competitive Junior Surfers. Retrieved Aug 17, 2014, from <http://research-hub.griffith.edu.au/display/n75e0ce53b-077b34e514e5c7bf62832cb>

- Mattila, V.M., Tallroth, K., Marttinen, M., & Pihlajamaki, H. (2007). Physical fitness and performance. Body composition by DEXA and its association with physical fitness in 140 conscripts. *Medicine and Science in Sports and Exercise*, 39(12), 2242–2247. PubMed doi:10.1249/mss.0b013e318155a813
- McGill, S., Melanie, B., Crosby, I., & Russell, C. (2010). Clinical tools to quantify torso flexion endurance: normative data from student and firefighter populations *Occupational Ergonomics*, 9, 55–61. doi: 10.3233/OER-2010-0181
- Melton, L.J., 3rd, Looker, A.C., Shepherd, J.A., O'Connor, M.K., Achenbach, S.J., Riggs, B.L., & Khosla, S. (2005). Osteoporosis assessment by whole body region vs. site-specific DXA. *Osteoporosis International*, 16(12), 1558–1564. PubMed doi:10.1007/s00198-005-1871-y
- Nana, A., Slater, G.J., Hopkins, W.G., & Burke, L.M. (2012). Effects of daily activities on dual-energy X-ray absorptiometry measurements of body composition in active people. *Medicine and Science in Sports and Exercise*, 44(1), 180–189. PubMed doi:10.1249/MSS.0b013e318228b60e
- Orwoll, E.S., Ferar, J., Oviatt, S.K., McClung, M.R., & Huntington, K. (1989). The relationship of swimming exercise to bone mass in men and women. *Archives of Internal Medicine*, 149(10), 2197–2200. PubMed doi:10.1001/archinte.1989.00390100035009
- Pink, B. (2013). Australian Health Survey: Updated Results, 2011–12. Retrieved August 17, 2014, from <http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/4364.0.55.003Chapter12011-2012>
- Refshauge, A. (2012). Risk factors contributing to chronic disease. Retrieved September 1, 2014, from <http://www.aihw.gov.au/WorkArea/DownloadAsset.aspx?id=10737421546>
- Sanders, K.M., Nowson, C.A., Kotowicz, M.A., Briffa, K., Devine, A., & Reid, I.R. (2009). Calcium and bone health: position statement for the Australian and New Zealand Bone and Mineral Society, Osteoporosis Australia and the Endocrine Society of Australia. *The Medical Journal of Australia*, 190(6), 316–320. PubMed
- Secomb, J.L., Sheppard, J.M., & Dascombe, B.J. (2014). Time-Motion Analysis of a Two Hour Surfing Training Session. *Int J Sports Physiol Perform*. doi: 10.1123/ijspp.2014-0002
- Pereira Silva, J.A., Costa Dias, F., Fonseca, J.E., Canhao, H., Resende, C., & Queiroz, Viana, M. (2004). Low bone mineral density in professional scuba divers. *Clinical Rheumatology*, 23(1), 19–20. PubMed doi:10.1007/s10067-003-0787-1
- Sinaki, M., McPhee, M.C., Hodgson, S.F., Merritt, J.M., & Offord, K.P. (1986). Relationship between bone mineral density of spine and strength of back extensors in healthy postmenopausal women. *Mayo Clinic Proceedings*, 61(2), 116–122. PubMed doi:10.1016/S0025-6196(12)65197-0
- Stark, A. (2013). Surfing Australia Annual Report. Retrieved 20th August, 2014, from <https://www.surfingaustralia.com/documents/annual%20report%202013.pdf>
- Taaffe, D.R., Snow-Harter, C., Connolly, D.A., Robinson, T.L., Brown, M.D., & Marcus, R. (1995). Differential effects of swimming versus weight-bearing activity on bone mineral status of eumenorrhic athletes. *Journal of Bone and Mineral Research*, 10(4), 586–593. PubMed doi:10.1002/jbmr.5650100411
- Tuuri, G., Loftin, M., & Oescher, J. (2002). Association of swim distance and age with body composition in adult female swimmers. *Medicine and Science in Sports and Exercise*, 34(12), 2110–2114. PubMed doi:10.1097/00005768-200212000-00037
- Vasikaran, S., Eastell, R., Bruyere, O., Foldes, A.J., Garnero, P., Griesmacher, A., . . . Kanis, J.A. (2011). Markers of bone turnover for the prediction of fracture risk and monitoring of osteoporosis treatment: a need for international reference standards. *Osteoporosis International*, 22(2), 391–420. PubMed doi:10.1007/s00198-010-1501-1
- Velez, N.F., Zhang, A., Stone, B., Perera, S., Miller, M., & Greenspan, S.L. (2008). The effect of moderate impact exercise on skeletal integrity in master athletes. *Osteoporosis International*, 19(10), 1457–1464. PubMed doi:10.1007/s00198-008-0590-6

- Walsh, J., Climstein, M., Heazlewood, I.T., Kettunen, J., Burke, S., Debeliso, M., & Adams, K.J. (2013). Body mass index for athletes participating in swimming at the World Masters Games. *Journal of Sports Medicine and Physical Fitness*, 53(2), 162–168. PubMed
- Warner, S.E., Shea, J.E., Miller, S.C., & Shaw, J.M. (2006). Adaptations in cortical and trabecular bone in response to mechanical loading with and without weight bearing. *Calcified Tissue International*, 79(6), 395–403. PubMed doi:10.1007/s00223-005-0293-3
- Watsford, M., Murphy, A., & Coutts, A. (2006). Energy expenditure and time–motion analysis during recreational surfing. *Journal of Science and Medicine in Sport*, 9(Suppl), 9. PubMed doi:10.1016/j.jsams.2006.12.018
- Weeks, B.K., & Beck, B.R. (2008). The BPAQ: a bone-specific physical activity assessment instrument. *Osteoporosis International*, 19(11), 1567–1577. PubMed doi:10.1007/s00198-008-0606-2
- Wroblewski, A.P., Amati, F., Smiley, M.A., Goodpaster, B., & Wright, V. (2011). Chronic exercise preserves lean muscle mass in masters athletes. *The Physician and Sportsmedicine*, 39(3), 172–178. PubMed doi:10.3810/psm.2011.09.1933