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ORIGINAL RESEARCH

Characterization of Activity and Cardiovascular Responses During Surfing in Recreational Male Surfers Between the Ages of 18 and 75 Years Old

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Participation in surfing has evolved to include all age groups. Therefore, the purpose of this study was to determine whether activity levels and cardiovascular responses to surfing change with age. Surfing time and heart rate (HR) were measured for the total surfing session and within each activity of surfing (paddling, sitting, wave riding, and miscellaneous). Peak oxygen consumption (VO_{2peak}) was also measured during laboratory-based simulated surfboard paddling on a modified swim bench ergometer. VO_{2peak} decreased with age during simulated paddling ($r = -.455$, $p < .001$, $n = 68$). Total time surfing ($p = .837$) and time spent within each activity of surfing did not differ with age ($n = 160$). Mean HR during surfing significantly decreased with age ($r = -.231$, $p = .004$). However, surfing HR expressed as a percent of age-predicted maximum increased significantly with age. Therefore, recreational surfers across the age spectrum are achieving intensities and durations that are consistent with guidelines for cardiovascular health.

Keywords: VO2peak, heart rate, aging

Surfing is a sport and recreational activity that originated in the 15th century and has increased in popularity throughout the years. In 2014, the International Surf Association reported there were an estimated 23 million surfers in the United States and the surf industry's annual revenue was $7.29 billion. Throughout the years, the demographics of surf participants have evolved to include children as young as 3 and adults in their 90s, with the median age of 34 years old (Wagner, Nelson, & Walker, 2011).

Due to the sport's growth in popularity, there is an increased interest in characterizing the physiological requirements of surfing (Barlow, Gresty, Findlay, Cooke, & Davidson, 2014; Farley, Harris, & Kilding, 2012; Meir, Lowdon, & Davie, 1991; Mendez-Villanueva, Bishop, & Hamer, 2006). Field studies performed in competitive and recreational surfers have reported that surfing consists of paddling, sitting or lying stationary, wave riding, and miscellaneous activities (e.g., diving under waves, wading, and swimming) at 44–58%, 28–42%, 4–8%, and 2–16% of the total time spent surfing, respectively (Barlow et al., 2014; Farley et al., 2012; Loveless & Minahan, 2010; Meir et al., 1991; Mendez-Villanueva et al., 2006). Approximately 50% of the surf session is spent paddling at an average heart rate (HR) of 143 beats per minute (bpm) (Meir et al., 1991), suggesting it is an aerobic activity. This is supported by peak oxygen consumption (VO_{2peak}) of 38–54 ml kg^{-1} min^{-1} during simulated paddling in 18–25-year-old competitive and recreational male surfers (Farley et al., 2012; Meir et al., 1991; Mendez-Villanueva et al., 2006). These data suggest that cardiovascular fitness is an important component of surfing. Furthermore, HR achieved during surfing is consistent with those recommended by the Centers for Disease Control and Prevention (CDC) for moderate intensity exercise (50–70% age predicted maximal heart rate) and is equivalent to other forms of recreational exercises such as canoeing, cycling, tennis, and front-crawl swimming (Meir et al., 1991).

The majority of studies characterizing the physiological requirements of surfing have primarily focused on professional surfers, which comprises only a small fraction of the surfing population (Farley et al., 2012; Mendez-Villanueva et al., 2006). Less is known about recreational surfers, and the physiological measurements are limited to surfers younger than 25 years old (Barlow et al., 2014; Bravo, Cummins, Nessler, & Newcomer, 2016; Meir et al., 1991). Therefore, there is currently a paucity of data characterizing surfing activity and cardiovascular parameters of recreational surfers across the age spectrum.

It is well known that maximal HR and VO_{2peak} decline with age (Fleg, 2012; McGavock et al., 2009). These cardiovascular changes that occur with aging may have an impact on surfing activity in the aging recreational surfer. Therefore, the purpose of this cross-sectional study was to characterize the surfing activity and cardiovascular responses during surfing in recreational male surfers from 18–75 years old. We hypothesized that aging surfers would have lower VO_{2peak} during simulated paddling in the laboratory and spend less total time surfing when observed in the field. In addition, we hypothesized that aging surfers would spend more time stationary and less time in other surfing activities. We also hypothesized that increases in time spent stationary with age would be associated with lower overall HR for the surfing session.

Methods

Subjects

Recreational male surfers were recruited from Southern California beaches for this study. Subjects participated in a field study (HR and activity measurements) or in a laboratory-based simulated paddling study (VO_{2peak}). All procedures were approved by the California State University, San Marcos Investigational Review Board (protocol 769612–1). Subjects were informed of the benefits and risks of the

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study and provided written informed consent before participation. Subjects participating in the field study reported their age, height, and weight, as well as provided information regarding their surfing frequency, experience, and proficiency level, the latter assessed utilizing the Hutt 1–10 scale (Hutt, Black, & Mead, 2001). In contrast, both height and weight were measured using a mechanical beam scale for the laboratory-based simulated paddling portion of this study. In addition, each subject's health was assessed using the AHA/ACSM health/fitness facility participation screening questionnaire and subjects reported no underlying cardiovascular disease or consumption of medication that would impact cardiovascular function.

Field Study

Some subjects for the field study provided consent to be video recorded (Canon Inc., Tokyo, Japan) during their surf session while others did not. In video-recorded subjects, a Polar RCX5 HR monitor (Polar Electro Inc., Kempele, Finland) was used to measure duration and record HR at 5-s intervals. Following completion of the surfing session, HR and video recordings were synchronized and analyzed at 5-s intervals. Surf activities were classified into one of the following four categories: stationary (lying or sitting on the board with no purposeful movement), paddling (movement of arms for the purpose of propulsion across the water), wave riding (standing on board while being propelled by a wave), or miscellaneous (swimming, wading, and diving under waves). These data were used to calculate average HR within each activity as well as the total time spent in each activity. It is important to note that stationary HR is likely not indicative of resting HR, but rather a reflection of recovery heart rate after a bout of wave riding, paddling, or a miscellaneous activity. For the participants that declined to be video recorded, a Polar FT1 HR monitor (Polar Electro Inc., Kempele, Finland) was used to measure duration and average HR for the entire surf session. Environmental conditions (water temperature, air temperature, wave intervals, wave direction, wave height, wind speed, and tide) for each surf session were obtained directly before each subject's surf session at their beach location using information from the National Oceanic and Atmospheric Administration's buoys located offshore (www.Surfline.com).

Simulated Paddling Study

Metabolic measurements and HR were measured with a TrueOne 2400 integrated metabolic measurement system (Parvo Medics, Sandy, Utah, USA) and a Polar FT1 HR monitor (Polar Electro Inc., Kempele, Finland), respectively, during simulated paddling. Subjects performed a graded exercise test on a modified swim bench ergometer (Vasa Inc., Essex, VT) with a surfboard attached. Subjects began the graded exercise test by paddling at 10 W and increased workload by 10 W every minute until reaching volitional fatigue. VO_{2peak}, ventilation (V_E), respiratory exchange ratio (RER), and HR were measured at 15-s intervals. The Borg scale was used to assess a subject's perceived exertion at the end of the simulated paddling test. Subjects that did not achieve a RER of greater than 1.1 or maximal heart rate within 10 bpm of their age-predicted maximum (220 – age) were excluded from the analysis and not included in the reported sample size.

Statistics

Data reported are means ± *SD*. One-way analysis of variance and Fischer's least significant difference (LSD) post hoc test were used to determine differences between age groups at an alpha 0.05 level. Heart rate was expressed in absolute terms (bpm) and as a percent of age-predicted maximal HR (220 – age) for each subject. Pearson's correlation coefficient (r) was used to determine if various endpoints (VO_{2peak}, HR, total time, and percent time in each activity) differed with age across all subjects at an alpha .01 level. The lower alpha value was selected due to the large number of correlations tested. Statistics were performed using SPSS version 22 (IBM Corporation, Armonk, New York).

Results

Subject Characteristics

A total of 228 recreational male surfers, ages 18–75 years old, volunteered to participate in this study. Of these 228 participants, 160 participated in the field study where heart rate was measured during surfing. Of the 160 field study participants, 79 subjects consented to be video recorded, whereas 81 did not. The remaining 68 subjects participated in the laboratory-based simulated paddling study. Combined subject characteristics (age, height, weight, surfing experience, and surfing frequency) are presented in Table 1. Subject surfing experience ranged from 2 to 62 years and surfing frequency ranged between 1–24 hr per week.

Field Study

The average total time spent in a surfing session was 66.6 ± 29.0 min. There were no significant differences in the total time spent in the surfing session between age groups (p = .837). Average total time surfing for each age group was: 18–29 = 66.7 ± 27.0 min; 30–39 = 67.2 ± 29.7 min; 40–49 = 61.9 ± 27.4 min; 50–59 = 66.0 ± 28.0 min; 60–75 = 71.0 ± 33.2 min. Average HR during surfing was significantly lower with increasing age (r = –.231, p = .004, Figure 1a). However, average HR as expressed as a percent of age predicted maximum HR increased significantly with age (r = .389, p < .001, Figure 1b).

Table 1 Age-Group Analysis for Subject Characteristics for All 228 Subjects

Age Group (years)	N	Age (years)	Height (m)	Mass (kg)	Surfing Experience † (years)	Surfing Frequency (hr/week)	Surfing Competency (1–10 scale)
18–29	58	23.4 ± 3.4	1.80 ± 0.09	76.0 ± 9.4	9.3 ± 5.1	9.08 ± 4.56	6.65 ± 1.91
30–39	53	34.6 ± 3.1	1.81 ± 0.08	81.9 ± 11.6*	18.0 ± 7.7	9.76 ± 6.98	6.92 ± 1.80
40–49	40	43.9 ± 2.9	1.77 ± 0.08	79.2 ± 10.7	24.5 ± 10.0	8.29 ± 5.52	6.73 ± 1.91
50–59	41	54.2 ± 3.0	1.76 ± 0.10	81.9 ± 11.1*	33.2 ± 12.2	7.49 ± 3.98	6.96 ± 1.32
60–75	36	64.6 ± 3.6	1.77 ± 0.07	82.9 ± 10.4*	38.4 ± 16.6	7.21 ± 3.29	6.57 ± 1.76

Values are means ± *SD*. * Denotes significant difference from 18–29 years old. † Denotes that all age groups differed significantly from all other age groups for surfing experience (alpha = .05).

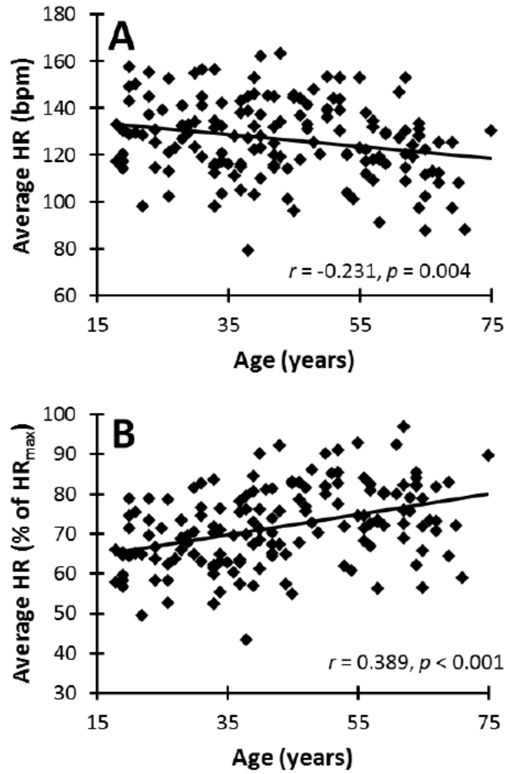

Figure 1 — Heart rates during surfing. Data expressed in beats per minute (A) and as a percentage of age-predicted maximum heart rate (B).

No significant relationships existed between age and percent time spent in any of the activities of surfing (paddling: $r = –.205$, $p = .070$; stationary: $r = .210$, $p = .064$; wave riding: $r = –.263$, $p = .019$; miscellaneous: $r = .015$, $p = .898$; Figure 2). Paddling HR and miscellaneous HR were negatively correlated with age (paddling: $r = –.295$, $p = .008$; miscellaneous: $r = –.410$, $p < .001$; Figure 3a–d). Neither stationary HR ($r = –.115$ $p = .312$, Figure 3b) nor wave-riding HR ($r = –.224$ $p = .049$, Figure 3c) were significantly correlated with age. Heart rate when expressed as a percent of age-predicted maximum was positively correlated with age for paddling ($r = .392$, $p < .001$, Figure 4a), stationary ($r = .392$, $p < .001$, Figure 4b), and wave riding ($r = .410$, $p < .001$, Figure 4c), but not with miscellaneous activity ($r = .176$, $p = .121$, Figure 4d).

Age was not correlated with any of the following subject characteristics: height, weight, hours per week spent surfing, and surfing competency (Table 2). Significant positive correlations existed between age and board height as well as age and years of surfing experience (Table 2). No significant correlations existed between age and the following environmental conditions: water temperature, wave height, wave interval, wave direction, wind speed, and crowd (Table 3). However, age was negatively correlated with air temperature and tide level (Table 3).

Simulated Paddling Study

VO_{2peak}, maximal minute ventilation (V_{Emax}), RER, maximal heart rate (HR_{max}), rating of perceived exertion (RPE), and maximal workload achieved during simulated paddling test for different age groups are presented in Table 4. VO_{2peak} and HR_{max} decreased significantly with age (VO_{2peak}: $r = –.455$, $p < .001$, Figure 5; HR_{max}: $r = –.407$, $p < .001$, *data not shown*). There was a nonsignificant trend for RER to be reduced with increasing age ($r = –.288$, $p = .019$, *data not shown*).

Discussion

The popularity of surfing has progressed since its inception and has transcended age barriers to incorporate participants of younger and older age groups alike (Wagner et al., 2011). Previous research

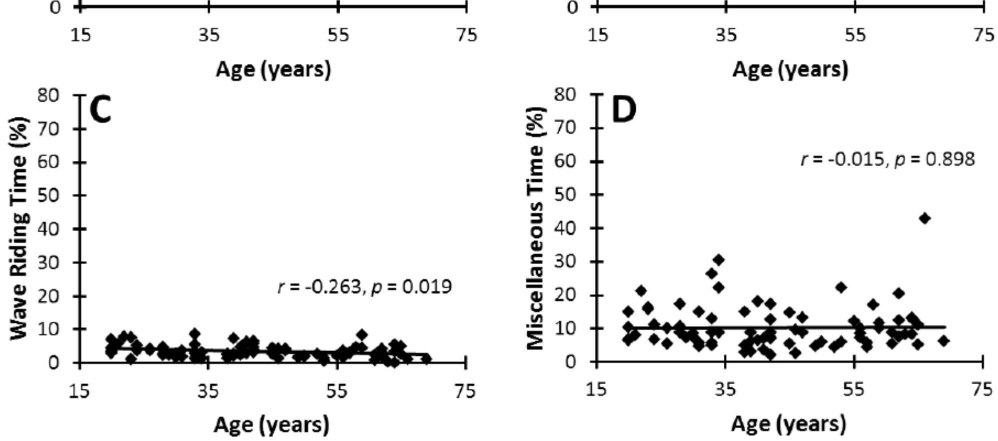

Figure 2 — Proportion of surfing time spent performing paddling (A), stationary (B), wave riding (C), and miscellaneous activities (D).

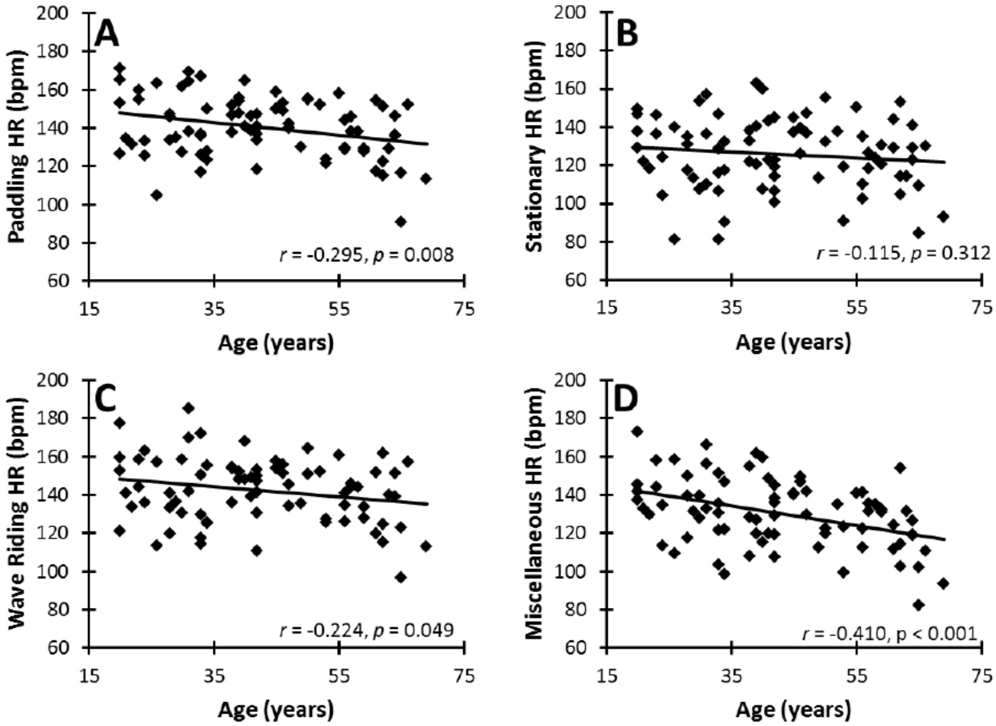

Figure 3 — Surfing heart rates during paddling (A), stationary (B), wave riding (C), and miscellaneous activities (D). Data expressed in beats per minute.

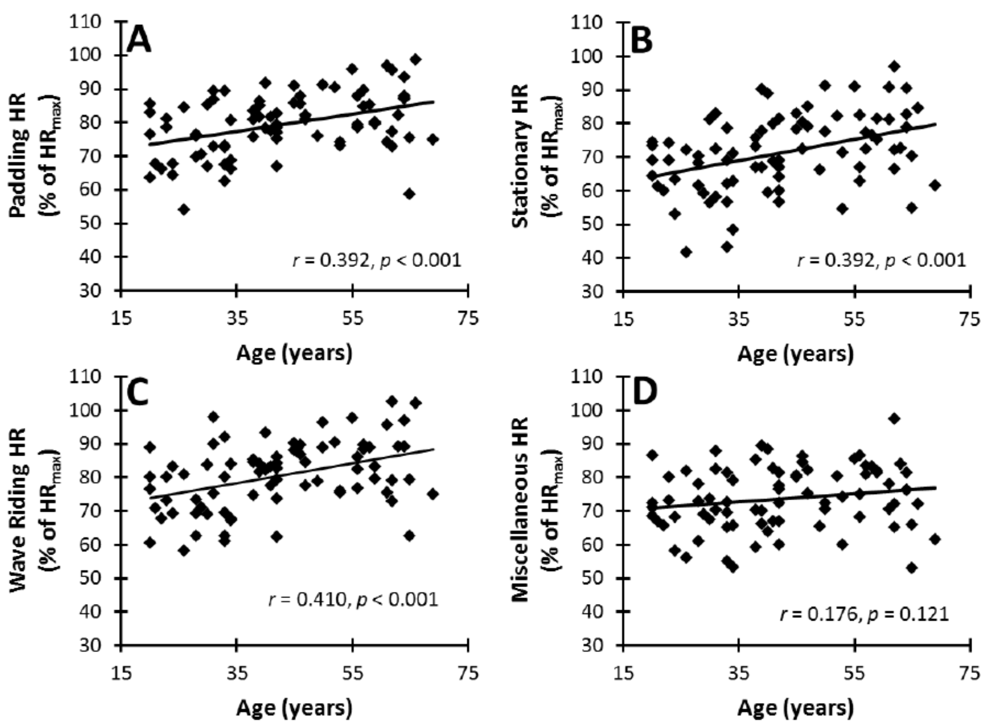

Figure 4 — Surfing heart rates during paddling (A), stationary (B), wave riding (C), and miscellaneous activities (D). Data expressed as a percentage of age-predicted maximum heart rate.

characterizing the physiological demands of surfing have neglected to account for the entire age spectrum of recreational surfers (Barlow et al., 2014; Farley et al., 2012; Meir et al., 1991; Mendez-Villanueva et al., 2006). The purpose of the current investigation was to characterize the surfing activity and cardiovascular responses during surfing in recreational male surfers between the ages of 18–75 years old. The current data were consistent with our hypothesis that aging is associated with reduced VO_{2peak} during simulated paddling. However, both total surfing time and time within each activity of surfing were not significantly correlated with age. These findings are

Table 2 Means, Standard Deviations, and Correlation Coefficients with Respect to Age for Subjects in the Field Portion of this Study

	Mean ± *SD*	Correlation with Age (*r*)	Correlation with Age (*p*)
Height (m)	1.78 ± 0.09	–.139	.043
Weight (kg)	80.3 ± 12.7	.164	.017
Board height (in)	89.5 ± 20.0	.476*	< .001
Hours per week	8.58 ± 5.27	–.148	.036
Years experience	21.5 ± 14.1	.702*	< .001
Competency	7.17 ± 1.51	.010	.938

* Denotes significant correlations at an alpha .01 level.

Table 3 Means, Standard Deviations, and Correlation Coefficients with Respect to Age for Subjects in the Field Portion of this Study

Environmental Factors	Mean ± *SD*	Correlation with Age (*r*)	Correlation with Age (*p*)
Air temp (°C)	18.9 ± 2.9	–.340*	.002
Water temp (°C)	18.9 ± 2.0	–.268*	.017
Wave height (ft)	1.91 ± 0.90	.126	.268
Wave interval (s)	11.6 ± 3.6	–.013	.911
Wave direction (°)	233 ± 47	–.010	.931
Wind speed (mph)	3.56 ± 2.98	–.095	.407
Tide level (ft)	2.58 ± 1.80	–.371*	.001

* Denotes significant correlations at an alpha .01 level.

Table 4 Age-Group Analysis of Peak Oxygen Consumption (VO_{2peak}), Minute Ventilation (VE_{max}), Respiratory Exchange Ratio (RER), Heart Rate (HR_{max}), Rating of Perceived Exertion (RPE), and Workload for 68 Subjects Participating in the Simulated Paddling Incremental Test

Age Groups	N	VO_{2peak} (ml/kg/min)	VE_{max} (l/min)	RER	HR_{max} (bpm)	RPE	$Workload_{max}$ (watts)
18–29	23	31.9 ± 7.1	113.4 ± 28.0	1.24 ± 0.06	179 ± 11	19.2 ± 0.1	96.4 ± 19.7
30–39	17	26.1 ± 5.3*	94.0 ± 19.8*	1.26 ± 0.12	167 ± 13*	19.4 ± 1.4	99.9 ± 22.8
40–49	9	28.5 ± 5.7	96.1 ± 20.6	1.26 ± 0.08	162 ± 16*	19.8 ± 0.7	87.8 ± 19.7
50–59	13	24.9 ± 5.1*	92.7 ± 13.4*	1.24 ± 0.14	166 ± 24*	19.8 ± 0.6	81.0 ± 14.4
60–75	6	20.9 ± 2.9*†	86.7 ± 24.0*	1.16 ± 0.14	154 ± 13*	19.2 ± 1.0	82.4 ± 19.1

* Denotes significant difference from 18–29 years old. † Denotes significant difference from 40–49 years old (alpha = .05).

noteworthy given one would speculate that individuals with lower aerobic fitness would spend more time sitting and less time paddling than those with higher aerobic fitness. In addition, and consistent with our hypothesis, increased age is associated with lower HR during paddling and miscellaneous activities (wading, swimming, and diving under waves). Therefore, these findings are the first to describe the impact of age on surfing activity and cardiovascular responses during recreational surfing.

Peak oxygen consumptions between approximately 38–50 ml/kg/min have previously been reported during simulated paddling in college swimmers and competitive surfers between the ages of 18 and 25 years old (Mendez-Villanueva & Bishop, 2005). In contrast, the current study demonstrates that the VO_{2peak} in recreational surfers between the ages of 18 and 75 years old are significantly lower, ranging in values between approximately 21–32 ml/kg/min. One can speculate that differences in VO_{2peak} reported in the current and past studies are likely a result of competitive status and age. It is well recognized that maximal oxygen consumption (VO_{2max}) significantly declines with age (Fleg, 2012, McGavock et al., 2009) and the VO_{2peak} data in the current study extend this relationship to upper-extremity exercise. To our knowledge, this is the first study to report the effects of aging on aerobic fitness during upper-extremity exercise. One can speculate that these reductions in VO_{2peak} during simulated surfboard paddling are indicative of alterations in oxygen delivery and utilization that occur with aging during lower-extremity or whole-body exercise (McGavock et al., 2009).

Given our current findings of decreased VO_{2peak} with age, we were surprised that there were no significant changes in the total time spent surfing and within the different activities of surfing (paddling, stationary, wave riding, miscellaneous) with age. One can speculate that aging surfers may be using their reported greater surfing experience to overcome age-associated deficits in aerobic capacity. In addition, the increased board height with age reported in this study may also suggest that aging surfers are utilizing

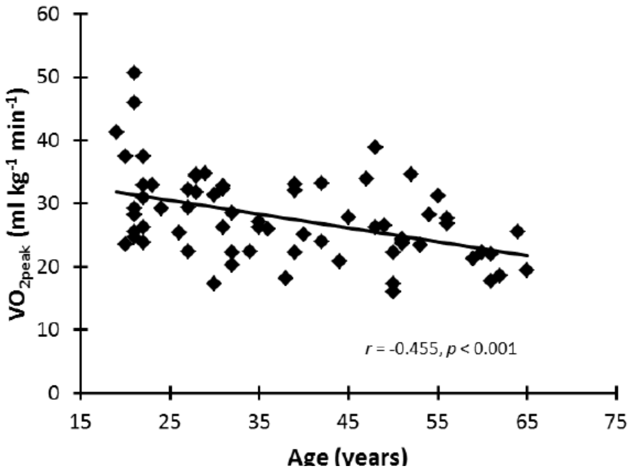

Figure 5 — VO_{2peak} during simulated paddling on a modified swim bench ergometer.

surfboards with greater buoyancy in an attempt to gain a mechanical advantage when paddling. In addition, our results demonstrating an inverse relationship between age and air temperature may be indicative of aging surfers choosing to surf earlier in the morning or on colder days when air temperature is lower and competition for waves may be decreased due to less crowded conditions. Lastly, the inverse relationship between tide level and age suggests that aging surfers prefer to surf at lower tides, when breaking waves typically generate more power. These factors likely allow surfers to maintain similar activity profiles across age even with decreases aerobic capacity.

Although there were no reported differences in time spent surfing or within the different surfing activities, the current findings demonstrate for the first time that average HR while surfing decreases with age. This is likely a result of the well-established reduction in HR_{max} that occur with aging (Fleg, 2012). In addition, HR within the specific surfing activities decreased with age during paddling and miscellaneous activities (Figure 3). While HR is frequently used to measure the intensity of an activity, we also chose to express HR as a percentage of age-predicted maximum HR to gain insight into the relative intensity. Our results suggest that increased age was associated with subjects achieving a greater percentage of their age-predicted maximum HR during paddling, stationary, and wave riding activities (Figure 4). However, it is important to note that the HR observed across the age range in our study are consistent with those of moderate-to-vigorous intensity exercise (50–85% of age-predicted maximum HR) as defined by the CDC. In addition to meeting the CDC's guidelines for exercise intensity, the surfers in this study greatly exceeded the recommendation for duration (150 min/week) as their reported surfing frequency was 8.51 ± 5.38 hr/week and did not differ among age groups. One can speculate that this excessive amount of time spent surfing by the subjects of this study reflects the enjoyment they derive from this form of physical activity.

There are limitations of this study that should be acknowledged. Due to the cross-sectional nature of this study, environmental conditions were never consistent among subjects and, therefore, may have impacted the HR achieved for each subject. However, the only two environmental factors that were significantly correlated with age were air temperature and tide. One could argue that the lower heart rate or higher percentage of age-predicted maximal heart rate reported in aging surfers may be indicative of cardiovascular adjustments associated with maintenance of core body temperature as a result of reduced ambient air temperatures. It has been reported that differences in ambient air temperatures of less than 10 °C (18 °F) do not significantly impact HR during exercise (Weller, Millard, Stroud, Greenhaff, & Macdonald, 1997). Therefore, mean temperature differences between age groups observed in the current study of 3.6 °C (6.5 °F) likely did not contribute to differences in HR with age. It is also important to note that the percentage of time spent in stationary and paddling activities in the current study were different than those previously reported in the literature for both competitive and recreational surfers (Barlow et al., 2014; Bravo et al., 2016 Farley et al., 2012; Meir et al., 1991; Mendez-Villanueva et al., 2006). Specifically, the current group of subjects spent a greater amount of time stationary (~55% vs. ~38%) and less time paddling (~32% vs. 49%) than what has historically been reported in the literature. One can speculate that these discrepancies in results may potentially reflect differences in subject populations (recreational vs. competitive) and/or regional differences in surfing activities (Southern California vs. Australia/New Zealand/United Kingdom). Lastly, the utilization of the age-predicted maximum HR equation as opposed to measuring maximum HR for determination of exercise intensity was a limitation of the current study. For this reason, exercise intensity data based on HR should be interpreted with caution.

In conclusion, results from the current study suggest that age has no impact on the time surfers spend in the water or in the various activities of surfing, and only modestly reduces their HR while surfing. Despite these reductions in heart rate, aging surfers continue to exercise at relative intensities that are matching, and even exceeding, younger surfers' efforts in the water. More importantly, this study demonstrates for the first time that recreational surfers across the age spectrum achieve exercise intensities and durations consistent with CDC recommendations for health. One can speculate that these health benefits likely translate into reduced risk for a variety of chronic diseases in older surfers. Specifically, exercise durations and intensities similar to those reported in this study have been shown to reduce the risk of diseases that are typically associated with aging, such as diabetes, cancer (breast and colon), hypertension, depression, dementia, coronary artery disease, and obesity (Sallis, 2015). Therefore, the results of this study strongly suggest that older individuals engaging in surfing will likely have decreased mortality rates compared with age-matched sedentary individuals. Future research will be necessary to substantiate these claims and to better understand the impact that surfing has on the susceptibility to a variety of chronic diseases.

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