

Research Articles and Essays

Metabolic Equivalents of Outrigger Canoe Paddling for Health Equity:

Methods of an Inclusive AccessMETs Study

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Abstract

People with disabilities have relatively low reported physical activity rates, increasing risk for chronic diseases and early mortality. This paper proposes a study design for evaluating the metabolic equivalents of outrigger canoe paddling, a culturally relevant means for promoting physical activity, for those with and without spinal cord injuries.

Keywords: Energy Expenditure, NHPI, METs

Metabolic Equivalents of Outrigger Canoe Paddling for Health Equity:**Methods of an Inclusive AccessMETs Study****Physical Activity, Health, and the Burden of Chronic Disease Risk**

Habitual physical activity (PA) is indispensable to the maintenance and improvement of physical and psychological health, and can be defined as “*a bodily movement produced by skeletal muscles that requires energy expenditure – including activities undertaken while working, playing, carrying out household chores, travelling, and engaging in recreational pursuits*” (WHO, 2023). More than a quarter of adults and over 80% of adolescents globally are insufficiently physically active according to standard guidelines - defined as engaging in at least 150 minutes of moderate intensity PA per week. Sedentary lifestyles causing physical inactivity (i.e., being insufficiently or not active at all) are common, especially in the United States (US). Physical inactivity is a risk factor for noncommunicable diseases, including obesity, diabetes, and cancer; it is the fourth-leading risk factor for mortality worldwide, decreasing life expectancy (United Health Foundation, 2021). Habitual PA reduces the noncommunicable diseases health burden and its risk factors by improving physiological and psychological well-being, as well as quality of life in the adult population (WHO, 2008).

Both the Center of Disease Control and Prevention and the World Health Organization emphasizes that guidelines for habitual PA are for everyone, across all communities, including people with disabilities (PWD) (CDC, 2021; WHO, 2023). While the

health benefits of habitual PA are well established by research and widely accepted by health practitioners throughout the world, the actual health risks from a chronic lack of PA are not evenly distributed across populations. People with disabilities (PWD) have disproportionately high noncommunicable diseases rates and lower PA. Globally, more than 15% of the population has a health condition resulting in disability (WHO, 2011). Within the US, more than 60 million adults experience disabilities (Okoro et al., 2018). In 2018, the prevalence of people of all ages with disabilities in the US was 10.4% (Erickson et al., 2020). PWD have three times greater risk of developing noncommunicable diseases than people without disabilities (CDC, 2021). While PA research often excludes PWD (Rios et al., 2016), consistent PA is critically important for PWD who meet PA guidelines less frequently than people without disabilities. Almost half of people with Spinal Cord Injury (SCI), for example, reported no PA at all (Rochi et al., 2017).

Some groups are at higher risk for disability. Native Hawaiian (NH) and Pacific Islanders (PI) have a higher risk for disability compared to many other racial/ethnic groups (Seto et al., 2018; Taira, 2022). NH and PI also have a relatively high noncommunicable diseases burden when compared to the U.S. population average (HDOH, 2022a; Mau et al., 2009). While PA promotion shows promise to reduce this burden (Mau et al., 2009), only one quarter of adults meet the PA guidelines in Hawai'i (An et al., 2016; HDOH, 2022b). In existing population-level surveillance instruments, NHPI are reported to have lower rates of PA than other racial/ethnic groups (HDOH, 2022b). National samples also find that NHPI have lower rates of PA than other racial/ethnic groups (Kruger et al., 2004).

Culturally Relevant Physical Activities

“Culturally relevant physical activity is exercise that is based on a population’s cultural customs and is a promising field for chronic disease prevention and management”

(Sentell, Wu, et al., 2023). Culturally relevant PA also promotes health from a “strengths-based” perspective, which is an alternative to a deficit-focused approach to improve health, focusing on community strengths, inclusion, and prevention rather than poor health outcomes and stigmatization (Tones, 2019). Though good examples do exist, more evidence is needed about culturally relevant PAs and their potential to influence positive health outcomes and reduce disease risk. Hula dance (culturally relevant practice of dance in Hawaiian culture), for instance, has been shown to reduce disease risk and provide strong health benefits (Kaholokula et al., 2021; Usagawa et al., 2013). Additionally, land-based practices in the outdoors also show considerable promise for health (Ahmed et al., 2021). “Green exercise” (exercise done outdoors), and “bluespaces” (activities in bodies of water in nature) provide positive outcomes (Barton & Pretty, 2010; Liu, 2021). PWD are significantly understudied in this literature. There is a strong need to build the evidence base for culturally relevant PA, especially for PWD, and to consider these for health interventions, as well as for public health promotion to reduce health inequities. Health professionals call for the establishment of culturally relevant PA interventions when working with minority populations (Look et al., 2012).

Outrigger Canoe Paddling

Outrigger canoe (OC) paddling (or “paddling”) may hold deep promise for health promotion generally, as well as assist with the reduction of health inequities for NHPI specifically, but research is scarce (Canyon & Sealey, 2016). Paddling is a popular, culturally relevant activity in Hawai‘i and beyond (*Hawaiian Outrigger Canoeing | It’s History & Revival To Date*, n.d.). A recent study found that in flagship state-level public health surveillance, 19.8% of the Hawai‘i population had participated in paddling in their lifetime with paddling participation much higher for NH (41.5%) and PI (31.1%) (Sentell, Wu, et al.,

2023). There were also high levels of lifetime engagement in paddling across gender. Notably, few statistically significant differences were seen for NHPI on engagement across demographic or health factors (Sentell, Wu, et al., 2023). Ongoing research-in-progress by our study team to explore this engagement in more detail through mixed methods also strongly supports the promise of paddling as a health intervention. Our quantitative research-in-progress has found that paddling engagement is highest during earlier periods of life and tended to decrease over age, but meaningful engagement is still seen in older ages, including over 65, showing relevance over the lifespan (Sentell, Thompson, Mika, et al., 2023).

An especially important characteristic of paddling is that paddling can be adaptive and thus inclusive for PWD. Paddling could be beneficial not only to health from a strengths-based, cultural perspective, but also specifically for PWD. Other community-based aquatic activities for PWD among US adults have shown to increase quality of life and adaptive paddling has been developed to expand aquatic PA opportunities to PWD (AccesSurf Hawai'i, 2023; Lopes et al., 2018).

Paddling METs

Outrigger canoe paddling shows enormous promise as a health promotion tool, but the physiological consequences of OC paddling on the ocean are unknown. While it could be assumed that OC paddling will influence the human body like that already described for many other well-studied aerobic PAs (e.g., running, cycling, cross country skiing), the lack of information still represents a critical barrier to both health promotion and scientific efforts. Clinicians, health promotion specialists, and exercise scientists, for instance, are less likely to include or focus on PAs that are not definable and referenceable in the research literature.

One of the most common starting points for studying PAs, is to characterize the typical metabolic intensity, or metabolic equivalent (MET), experienced by the body during

standardized measurement conditions. As a reference, a 1.0 MET value is equivalent to the energy cost of sitting quietly at rest, which is generally assumed to be 3.5 mls/kg/min (rate of oxygen uptake per kg per minute) (Jetté et al., 1990), which is also an assumed population average for resting metabolic rate for people without physical impairments (*ACSM's Guidelines for Exercise Testing and Prescription.*, 2006). MET values are commonly classified by intensity, where values from 1.0-1.5 METs are considered “sedentary,” 1.6-2.9 METs are “light” intensity, 3.0-5.9 are “moderate” intensity, while ≥ 6.0 METs are classified as vigorous intensity PA (Jetté et al., 1990). Hence, when a person is engaged in moderate intensity PA, one is expending 3.0 to 5.9 times more metabolic energy than when sitting at rest. The practice of determining MET values for different human activities has been occurring for many decades. So many MET values have been reported in research literature, in fact, that an all-inclusive list of values has been compiled into a compendium. The most recent addition of this compendium – The 2024 Compendium of Physical Activities (February 2024) – has been subdivided into three separate compendiums by population – the Adult Compendium (18-59 years old; 1,114 PAs), the Adult Wheelchair Compendium (124 PAs), and the Older Adult (60+ years old) Compendium (427 PAs) (Conger et al., 2024; Herrmann et al., 2024; Willis et al., 2024). Even though the 2024 Compendium of Physical Activities has summarized the MET values for 1665 individual PAs (which is nearly double the number of PAs reported for the 2011 Compendium), OC paddling is not included as one of evaluated PAs for any population of adults. Further, with notable exceptions (e.g., hula), most METs are calculated for “Western” activities (e.g., jogging).

Additionally, most METs are for activities on land, but water sports are also popular, and the ocean has important cultural value and healing attributes (Amrhein et al., 2016; Huffer, 2017). Some water activities, such as canoeing and rowing are represented in

the Compendium (Ainsworth, et al. 2011; Ainsworth, et al., 2011) However, these MET values are based on canoeing (i.e., without an outrigger arm) and rowing rather than OC paddling. A paddler in an outrigger canoe paddles with one paddle with a “T-top” and alternates paddling sides (left and right). A truly unique characteristic of the outrigger canoe itself is the stabilizing outrigger float called “ama” to the left of the boat. The ama is attached to the canoe with two connectors called “iako” (Haley & Nichols, 2009) and collectively – the ama and iako – have a stabilizing effect on the canoe during rough water conditions. There are options for 1-, 2-, 4-,6- and 12-person outrigger canoes for recreational usage, as well as for short (regatta) and long-distance OC races. While METs for other sports do provide plausible benchmark values, they are dramatically different sports. A rower, for example, uses two paddles, sits backwards, and is “attached” to the boat. Without an outrigger, a canoe can go backward more easily and canoeists are usually solo or in pairs in fresh water, less commonly in open ocean. OC paddling, in contrast, is designed for the open ocean and the paddler faces forward while always going in one direction. The complete lack of MET information for OC paddling in the 2024 Compendium represents a clear foundational gap in the research literature.

Establishing the METs for OC paddling would lay an important foundation to expanding the knowledge of the effectiveness of paddling as a health intervention and for public health promotion. Establishing METs also allows a direct comparison of metabolic intensity to other well-studied sports and builds critical knowledge for future research, including potential benefits, plausible effect sizes, necessary “doses,” and adaptations for different clinical groups. This also builds the evidence base in research to resolve health inequities for NHPI from a strengths-based perspective. It also addresses other important scientific knowledge gaps. Few METs are calculated for PWD, a large and important

research gap for PA generally. Emerging research has found that established METs for people without disabilities are often not appropriate to use for PWD, such as paraplegia (CDC & ACSM; Collins et al., 2010; Lee et al., 2010). Thus, a study that could focus on establishing OC paddling MET values for several populations simultaneously could be highly beneficial.

Study Purpose and Aims

The primary objective for this study is to measure and characterize the range of typical metabolic intensities (i.e., METs) experienced when outrigger canoeing for people with and without disabilities. We did so in the state of Hawai‘i. OC paddling is not only a culturally relevant and popular PA in the state of Hawai‘i, it’s a popular PA with NHPIs and has a proven history to be adaptive and thus inclusive for PWD. Further, the state of Hawai‘i has the largest population of NH in the United States, as well as a higher relative prevalence of people of all ages with disabilities than that reported in the US (10.9% in Hawai‘i versus 10.4%) (Erickson et al., 2020).

The study has two specific aims:

Aim #1: Establish Paddling METs for people without SCI. This aim will be accomplished using standard 6-person outrigger canoes (i.e., OC6, which includes 5 paddles and 1 steersperson) in open ocean water. During each canoe run, multiple paddlers will be wearing instrumentation for the direct measurement of metabolic intensity and heart rate.

Aim #2: Establish Paddling METs for PWD. Using the same methods as described for Aim #1, but for paddlers with Spinal Cord Injuries (SCI).

For both paddlers with and without SCI, recreational and competitive paddlers will be recruited and we hypothesized that the energy expenditure for paddling, even at the lowest intensity evaluated, will meet, or exceed, the MET level defined as moderate intensity (≥ 3 METs), while the highest paddling intensities tested will also meet or exceed the MET level defined as vigorous intensity (≥ 6 METs).

Community-based

This study is a community-participatory research (CBPR) study (Briss et al., 2004; Fong et al., 2003). This study is a collaboration across universities, non-profit organizations, canoe clubs and paddlers with the motto of “from paddlers, with paddler, for paddlers.” This study is led by a post-doctoral researcher and paddler who has a bridge position across the Department of Health (DOH), Chronic Disease Prevention and Health Promotion Division, Surveillance, Evaluation and Epidemiology Office, and the University of Hawai‘i (UHM), Office of Public Health Studies. Additional DOH and UH staff are on the research team, as a Co-Investigator and Mentor. Our community partner, AccesSurf Hawaii (“AccesSurf”), founded in 2006, has been a leader in adaptive ocean sports, including swimming, surfing and paddling (AccesSurf Hawai‘i, 2023) and adapting equipment to allow people with all abilities to participate. For an adaptive paddler with SCI, for example, this includes attaching a backrest and straps to help the paddler sit in the wa‘a or va‘a (canoe; wa‘a used in this paper) and an adaptive paddle if needed. One of the investigators in our study team is the Training and Innovation Director at AccesSurf, is an international ranked competitive adaptive paddler who is NH with a SCI, an expert of adapting ocean sports and a well-respected mentor with deep lived experience of the holistic benefits of paddling (Outrigger Duke Kahanamoku Foundation, 2023). The main partnering canoe club is Honolulu Pearl Canoe Club, with the

representative, Penny Kalua being the community liaison for this study. She and a partner were also the founder of the Hawai'i Adaptive Paddling Association in 2012, which was “merged” with AccesSurf Hawai'i's adaptive paddling program in 2019. This study also included cultural practitioners. We established a scientific advisory committee and a community hui, who with the community liaison are helping to plan and execute the study.

Proposed Study Methodology

Study Design. The study will be a cross-sectional, correlational, quantitative analysis of data to evaluate the METs of OC paddling. This study is currently planned for the Spring of 2024.

Participants. Criterion sampling (Patton, 1990) will be used to recruit up to 60 experienced adult OC paddlers with and without SCI, and one to two experienced steersperson. To successfully volunteer for this study (i.e., inclusion criteria), study participants must be experienced paddlers who are safe and confident in the open ocean and comfortable wearing the testing equipment during data collection for 45 minutes. Exclusion criteria include any of the following: Being <18 years of age; Not reporting female or male gender; inexperienced or beginner paddlers (<30 times total); Currently pregnant; Anyone at higher risk for an adverse exercise-related cardiac event. Health screening will be performed using the ACSM Health Screening Algorithm, unless appropriate medical clearance is provided (Riebe et al., 2015). In addition, all participants will complete an Informed Consent Document that has been reviewed and approved by the Internal Review Board (IRB) from the University of Hawai'i (Honolulu, HI USA).

Measurement Procedures. After screening, eligible study participants will be invited to meet with the study team for testing during the Spring of 2024 at Mauiola Ke'ehi (on the South Shore of O'ahu) (Honolulu, HI USA). This location is not only the home for many local canoe clubs, and a popular location for local OC competitive events, but also a

meaningful place for health for Kanaka ‘Ōiwi (Kaholokula, J.K., n.d.; *Mauliola Ke ‘ehi* 2023). Participants will be invited to participate as part of a group – i.e., five paddlers and one steersperson – where four paddlers would wear measurement equipment, and the steersperson and paddler would call and relay commands for operating the canoe on the water. Prior to getting in the canoe, several demographic measures were collected for the setup of the metabolic testing equipment: Age (date of birth), body weight, and body height. For paddlers without SCI, we will record body weight and collect self-reported height, paddlers with SCI were asked to report their last documented weight and height from their medical provider. Participants will also complete a survey requesting information about paddling history and exercise routine. For those with SCI, questions about each person’s SCI injury (level and length of injury) are included. Additionally, once accepted into the study, the paddlers with SCI will meet with a certified physical therapist to perform tests relevant to the functioning of the paddler (Collins et al., 2010) (sitting/standing balance, core, length/leg, shoulder hand grip strength) (Gorman et al., 2014; Wadhwa & Aikat, 2016; Westrick et al., 2012). These additional tests will provide the functional range for these SCI paddlers which, we hope, can be used to help explain their metabolic and cardiovascular responses during OC paddling.

Next, with the canoe already in the water and paddlers in their designated seats, each of the four paddlers will be fitted with the measurement equipment: 1) Telemetry-based chest strap for the measurement of heart rate; 2) Face mask and headcap for wearing the portable metabolic measurement. After the equipment is fitted, the canoe will leave shore under the verbal guidance of the steersperson and the unmasked paddler. Each paddling session will begin with about 15 minutes of warmup at a range of self-selected intensities and then a 2-minutes break. Next, the paddlers will be instructed to paddle at an “easy” intensity for 5 consecutive minutes with the goal of being as consistent with their paddling stroke and effort

level as possible. This 5-minutes “easy” effort was followed by another 2-minute break, and then another 5-minutes “moderate” or “intermediate” intensity for another 5 minutes. Following another 2-minutes break, the canoers then paddled 5 more minutes at a “high” intensity. The goal with this strategy was to measure both metabolic and cardiovascular intensities at three discretely different levels (i.e., for the assessment of Aims #1 and #2). Following the last 5-minute piece, there will be a 1-minute break before the paddlers are instructed to paddle at the highest intensity possible for 2-minutes, followed by another 1-minutes break, and then a final 2-minutes maximal effort again.

From the portable metabolic measurement systems we will collect direct measures of absolute oxygen consumption (AVO_2 , L/min), which are then converted to a measure relative to body mass (RVO_2 , ml/kg/min). This RVO_2 measure is then divided by 3.5 ml/kg/min – a standardized, or population value, of resting metabolic rate – to derive a measure of metabolic equivalents, or METs: $\text{METs} = \text{RVO}_2 / \text{METs}$. The mean MET value from the last 2-minutes of each 5-minutes paddling bout will be used to represent the metabolic intensity of paddling at the three steady-state conditions. Finally, both HR and HR% for each paddler will be computed from the same 2-minutes of each 5-minutes bout as described for METs. The %HR will be computed as a percentage of age-predicted maximal HR ($\text{APMHR} = 220 - \text{Age}$), where $\text{HR}\% = (\text{HR} / \text{APMHR}) \times 100$.

Data analyses. Statistical analysis Intraclass reliability (ICC) for internal consistency will be computed between the last two minutes for each metabolic and cardiovascular variable. The transformed metabolic (RVO_2 , METs) and cardiovascular (HR, %HR) variables will then be summarized (Mean \pm SD) for descriptive purposes. To satisfy the study objectives, mean MET values at intensity (“easy,” “moderate,” “high”) for both paddlers with and without SCI will be statistically compared to both 3.0 and 6.0 MET threshold cut-points

(CP), respectively, using two-sided T-tests at a 0.05 alpha level. Effect sizes (ES) for comparisons will also be calculated using Cohen's d (10): $d = (EE_{METs} - CP) / SD_{METs}$, where EE_{METs} and SD_{METs} are the sample mean and SD for each paddling condition, and CP is either 3.0 or 6.0 and corresponds with the moderate and vigorous intensity CPs, respectively.

Study Limitations. While the study team is well prepared to address both expected and the unexpected challenges certain to present themselves with this study, there are several limitations worth addressing apriori. First, sample size will likely be relatively small for the SCI paddling group. There is usually a relatively low number of PWD, e.g. SCI in any given community (Craven et al., 2014; Martin Ginis & Hicks, 2005). Comparable research that analyzed METs of aquatic exercise included either 9 or 14 participants. Research of METs and energy expenditure within populations with SCI used between 31 and 100 participants; however, they were performing 10 and 27 activities, hence only a few participants per activity (Collins et al., 2010; Lee et al., 2010). Low participant numbers can be common in MET studies, such as MET evaluation for hula (Usagawa et al., 2013). Regardless, our partner – AccessSurf - has strong reach into communities of PWD who paddle, mitigating this concern. Second, the generalizability to the general adaptive paddler population might be limited due to the exclusion of people with various additional diseases/symptoms (common in the population with physical impairment). While this is a legitimate concern, it is simply not possible to focus on every possible population of adults within the context of a single study. Third, MET measurements may vary with the ocean and weather conditions both within and between days of testing. Ideally, all measurements (i.e., OC paddling) should be done in relatively calm ocean and weather conditions so that metabolic and cardiovascular measurements between test groups are most comparable. Our study team does have some degree of flexibility with the window of measurement. As such, some testing may be

rescheduled for another day if cancellation is needed. Regardless, data collection will not occur on days where the ocean conditions are determined to be too rough or dangerous.

Dissemination plan. To report back to all paddlers, we plan to visit regattas and communicate them to canoe clubs, as well as at the world sprints event by the International Va'a Federation (IVF). The results of this study will be disseminated first to the participant paddlers with and without Spinal Cord Injuries (at regattas, email), then the rest of the AccesSurf community (Board of Director meeting, events, social media), Honolulu Pearl Canoe Club, and the paddling community in Hawai'i (through the racing associations). The Hawai'i Department of Health (HDOH) will help disseminate these findings from a practice perspective. Next, a summary of select findings will be reported at select public health and sports medicine conference and results manuscripts will be submitted to peer-reviewed scientific journals.

Expected Findings and Future Research.

This study has clear implications for health disparities research for strengths-based health promotion with cultural relevance for NHPI. Additionally, if it can be shown that adaptive paddling reaches the moderate-to-vigorous PA thresholds, it can help promote (adaptive) paddling as a PA option for people with physical impairment (and other aquatic activities) in places where water sports are possible. If adaptive paddling can be quantified as a moderate-to-vigorous PA option then PWD might be encouraged to engage in more (adaptive) paddling, helping to meet the PA recommendations (Haskell et al., 2007). Hence it can help prevent noncommunicable diseases and lower future health care costs in this population.

This work is highly relevant for populations with known health inequities and

considerable community strengths that should be leveraged for health promotion. Notably, this PWD inclusive study with a strong transdisciplinary research team with deep community engagement, will provide foundational METs data to reduce health inequities for NHPI and for PWD, an important research gap, and addresses other limitations in the health and research literature. (This study is funded by OlaHAWAII [NIH/NIMHD U54MD007601]).

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