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Energy expenditure compared to mental focus & score in three modes of golf transport/play

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Abstract

How does energy expenditure (EE) vary in golf based on the mode of transport and play? Does walking in some form enhance mental focus and decrease scores? Do all forms of golf play qualify as health-improvement activity? To determine potential golf participation benefits, a pre-study VO2 test was used to compare EE from the trials. The ten subjects (n=10), six males and four females, were all regular golfers at an accessible public golf course. Subjects played nine-hole rounds using a motor cart (MC), pushcart (PC), and electric trolley (ET)while wearing a portable metabolic system. Data points were recorded and averaged for O2/L/min and converted to kcal per hour, oxygen consumption in VO2 ml/kg/min, and heart rate (HR). Subjects kept score and completed a mental focus survey, which rated tee shots, second to fourth shots, and the short game from 100 yards in for each trial. The MC play had the least average expenditure of the three modes of transport and play (211 kcal/hr.), followed by the ET (236 kcal/hr.) and the PC (288 kcal/hr.), p = 0.001. The ET had the highest mental focus score (6.63/10), followed by the PC (5.67) and the MC (5.01), p = .015. The average score to par was one stroke better for the two walking modes versus the MC (10.3 vs. 11.5), p= 0.1906580. Walking while playing had better potential health effects while improving positive focus and scoring benefits compared to a motor cart. Golf in the walking modes is a moderate-intensity physical activity, while MC play is lower in health and fitness benefit.

Keywords: Golf; Energy Expenditure; VO2 Max; Kilocalories; Mental Focus; Pushcart; Electric Trolley

1. Introduction

Golf has surged over the last ten years as a recreational sport activity. Over the two years of the pandemic, golf growth spurted upward as it allowed participants time outside in a recreational environment with a robust set of perceived health and social benefits [1, 2]. However, do the perceived benefits match reality regarding health or fitness contribution?

There has been continuing debate about whether golf is a sport or an activity and what is the level of physical benefit. Limited studies have attempted to ascertain how golf contributes to health. Prior investigations have used metrics such as steps, distance, heart rate, movement patterns, and in rare cases, actual energy expenditure via expired gases to view health or fitness benefit [3, 4, 5]. While not conclusive, as golf is a complex activity with many dimensions of play, the investigations have strongly indicated that golf contributes to health as a moderate-exertion physical activity [4, 5, 6]. It is better than just walking, in large part due to the increased metabolic demands of the terrain, and total energy expended and the golf swing itself.

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However, for the last ten years, and specifically, the last two years with the pandemic, walking while playing has grown as a form of transport and play especially within many public/accessible golf courses. Furthermore, the ways to walk as a transport mode have expanded from just a carry bag to include more sophisticated pushcarts (PC) and electric trolleys (ET). Motor carts (MC) are still used, yet with the pandemic, many golfers chose to walk in some form as it was perceived to have both a social aspect with the other golfers and provide exercise. How do these different forms of transport affect energy expenditure and thus health and fitness contribution? An even more interesting question is, does one form of transport have an advantage in promoting mental focus and lowering scores?

With those questions in mind, this beta investigation focused on investigating EE with various transport and play modes and then correlating EE to mental focus rating and score. Previous studies show that walking with a pushcart and carry bag have the same energy expenditure [7]. PCs have gained tremendous use over the last five years, so they were chosen over carry bags for study. In terms of use by golfers over the age of 40, carry bags are still used, yet pushcarts are steadily gaining more share in this age demographic. In addition, ETs, which carry and propel the bag with a motor, have also gained usage share for the last five years, especially during the pandemic. While more prevalent in the U.S. than in other countries, many participants prefer to play golf in an MC, or have some physical limitation that keeps them from some form of walking transport/play. Walking is even more appealing and prevalent as the age of the golfer increases because golfers see walking and golfing as a better exercise than just walking alone, especially considering social interaction during golf.

A vital feature of the investigation that has yet to be researched or reported in the literature is the relationship of the mode of transport to mental focus and score. One would venture walking utilizes more energy than riding in a cart, yet does it increase mental focus and decrease score?

2. Material and methods

Subjects were recruited from regular golfers at the CommonGround Golf Course, home of the Colorado Golf Association, in Aurora, Colorado. Study applicants had to meet a minimum age of 45, play at least once per week at the course, and walk in some form at least 50% of their golf time. Applicants completed a set of health history questionnaires and participatory consent and waiver, which the Colorado Center for Health & Sports Science (CCHSS) IRB reviewed. Any subjects with medical issues that would interfere with play or testing were removed from the consideration pool. Upon final review, ten (n=10) subjects, six males (n=6) and four females (n=4), were prospectively selected. After all documents were reviewed and completed, all selected subjects performed a VO2 max test on a cycle ergometer using gas exchange (OxyconMobile, Vyaire Medical, Mettawa, United States) [8, 9]. Respiratory Exchange Ratios (RER) of 1.10 or greater were combined with volitional, maximum effort to signal test termination.

Table 1 Subject Demographics

Subject #	Weight/lbs.	Height/inches	Age	VO2/ml/kg/min	AT/ml/kg/min	Max HR	Handicap/9 Holes
1	220	71	69	22.8	19.1	148	12.15
2	220	74	73	29.5	19.4	138	6.9
3	163	69	69	33.9	22	152	7.25
4	165	69	48	31.8	21.9	148	0.05
5	220	74	58	30.4	22.4	144	5
6	228	71	69	25.4	13.9	124	12.1
7	105	60	59	26.9	19.2	136	6.2
8	183	65	65	20	13.7	148	16.5
9	114	67	60	26.9	15.5	131	21.5
10	183	67	66	14.5	12.3	146	21
Mean	180.10	68.7	64	26.21	17.94	141.5	10.87

The subject profile demographics, including VO2 max scores, Anaerobic Threshold (AT), are listed in Table 1. To standardize test conditions, the subjects received a set of trial guidelines. This included setting a test time that was exact or similar for all rounds. It was deemed necessary for the subjects to keep their nutritional intake constant for the time frame of the three trials. In addition, the subjects were directed not to change equipment during the study (clubs, balls, shoes, and equipment) and not embark on any golf instruction during that time. The subjects were also instructed to set

testing times/dates after a day of rest or cessation from golf play to ensure they entered the trial that day in a rested state with optimum awareness of mental focus. Ideally, there were seven days between trials to account for regular golf play without measurement conditions. If the subject suspected Covid or another illness with a respiratory nature, they were instructed to secure medical evaluation before allowing the trial that day.

On-course testing consisted of using a VO2 Master metabolic analyzer (VO2 Master, Vernon, Canada) and a standard Hans-Rudolph mask. Figure 1. A Wahoo heart rate monitor/strap was integrated into the unit. The measurement device was used because of the very minimal weight, and the field of vision was reasonable, given the size of the mask/analyzer on the subject's face. Beta testing with four sessions with one subject revealed that the VO2 Master had the same O2 and primary respiratory data over test holes [10], but with less encumbrance and interference with the golf swing than the OxyconMobile. Masks and subsequent head straps were fitted to the subject using a Hans-Rudolph sizing tool, and then the same size for each subject was used throughout the study.

Figure 1 VO2 Master Sensor & HR Mask Combination

Subjects could play in the metabolic sensing unit with minor impairment and distraction. The unit was powered up for each trial and underwent its standard calibration sequence. During the first session, the subject hit practice balls before the first session to gain familiarity with the equipment. Using the first nine holes of the course, order of play was MC, PC, and ET for each subject. Subjects used the sensor configuration for tee shots, all shots to get to the green, and the short game. Figures 2, 3 & 4.

Figure 2 Driver Golf Swing with the Metabolic Sensor

Figure 3 Second Shot with the Metabolic Sensor

Figure 4 Putting with the Metabolic Sensor

The MC and PC were used first because all subjects had substantial experience with those modes of transport and play. This order would allow additional comfort with the analyzer before the additional potential focus requirements for the operation of the ET. In MC play, the subject was the rider, and the test administrator was the driver who monitored the data, which was recorded to a cell phone, then converted to 30-second averages, and, post-round, loaded to a database in a standard spreadsheet. All subject trials were monitored and observed on course.

Figure 5 Pushcart used for all participants

To further standardize play, the same PC was used for all participants (IQ360, Big Max Golf, Vienna, Austria), which allowed easy steering with a pivoting front wheel. The handlebar was adjusted for the preferred pushing height. Figure 5. The ET used has a remote control allowing sending the cart without tethering direction to the subject, and has various safety features (XR4, BatCaddy, Novato, California, United States). Figure 6. Subjects were given additional instructions on ET usage with small hills and directional navigation. Subjects were allowed to practice steering and braking before starting their round to understand cart usage with each walking option. As weight will affect energy expenditure with the PC, subjects were required to use their bag or a standard golf bag (Big Max Hybrid, Big Max Golf, Vienna, Austria) with minimum inclusions. Non-necessary items were placed on the monitoring MC for use if needed.

Figure 6 Electric Trolley used for all participants

For MC play, the cart would be parked in reasonable proximity to the ball, and the subject would exit, play their shot, and then return to the cart. Figure 7.

Figure 7 Motor Cart play

During the actual trial, the temperature varied between 64 and 86 degrees Fahrenheit (17.7 and 30 degrees Celsius). If the temperature was above that 86-degree Fahrenheit mark, the trial was moved to another day/time where the temperature would not result in undue mask discomfort and distraction. If the humidity was an issue during a trial, as determined by the subject, the sensing system was paused briefly, and the mask interior was wiped dry and then re-started. After round completion, data was averaged for actual VO2 in ml/kg/min and O2 in liters. The physiological results included an O2 measure per minute converted to kcal per hour (using the accepted five kcal per liter of O2 consumed), VO2 per minute, and average heart rate.

Upon completion of each trial, subjects reported their score over par for the nine holes. The mental focus was assessed using a scale developed for the project that used a 1-10 ranking system combining focus and feelings of energy. *Five* on the scale was their average mental focus, attention, and feelings of energy. A rating of *one* meant the subject felt no energy/focus, while the number *ten* was optimal/perfect focus and energy. The rating scale included tee shots, second to fourth shots, and the short game defined by 100 yards and in, including putting. The three ratings were combined and averaged to give one, overall number. This simple scale was used after initial testing with two sample golfers to determine if the ratings reflected the broad variability and possibilities concerning mental focus in golf [11-15].

3. Results

HR in each mode was averaged, with the motor cart having the lowest average at 83 BPM. The ET and PC were higher at 90 and 99 BPM, respectively [16]. The differences between groups were significant at p= 0.00111 via one-way ANOVA, with SPSS used to calculate all statistics. The average heart rate numbers are presented graphically in Figure 8.

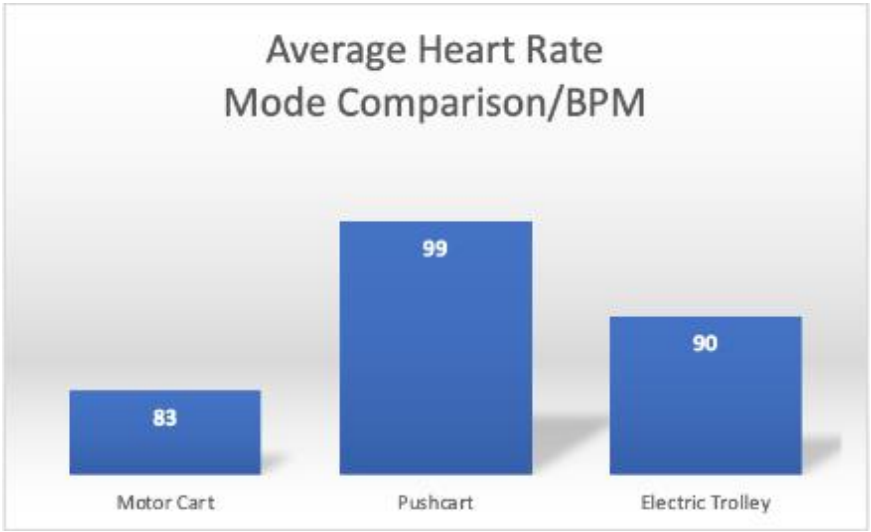

Figure 8 HR by Mode Comparison

EE for the three modes of transport/play is compared for VO2 as ml/kg/min and kcal per hour in Table 2. A one-way ANOVA revealed high significance between the three measures at p= 0.00528. The MC play had the lowest average VO2 at 8.9 ml/kg/min, while the ET was higher at 9.88, with the PC score being the highest at 12.11. The comparison for VO2 is represented graphically in Figure 9.

Table 2 Energy Metrics by Transport/Play Mode

Subject #	MC VO2	PC VO2	ET VO2	MC Kcal/Hr	PC Kcal/Hr	ET Kcal/Hr
1	8.38	10.80	9.80	250	317.1	295
2	8.00	9.80	9.95	220	276	295
3	8.50	14.50	10.50	183	320.4	224
4	11.80	13.90	9.70	249.9	271	177
5	9.42	15.70	12.90	282	456	382
6	7.98	10.20	8.21	250	318	255
7	9.60	8.90	9.90	130	123	135
8	8.30	14.00	8.87	207	341	221
9	8.10	14.10	9.70	132	227	149
10	8.90	9.17	9.31	206.7	228	231
Mean	**8.90**	**12.11**	**9.88**	**211**	**288**	**236**

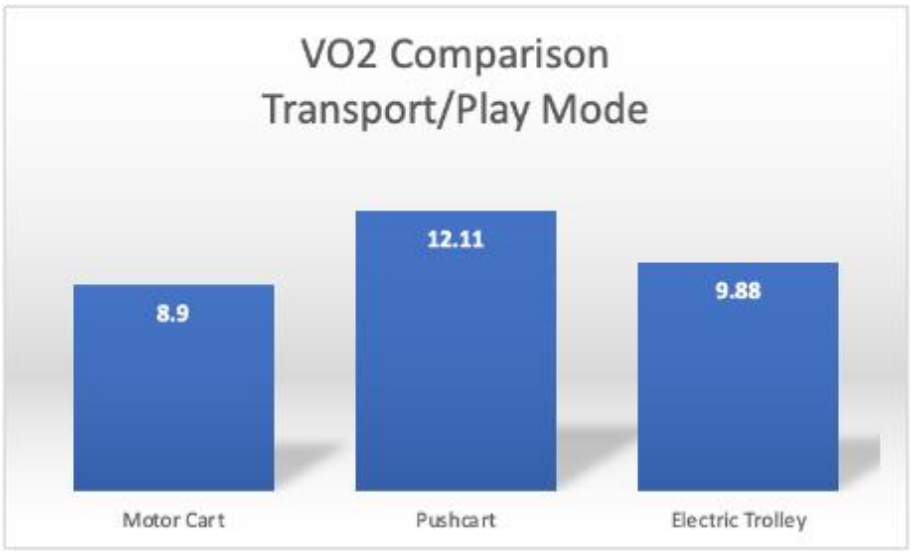

Figure 9 VO2 Comparison/Transport/Play Modes

When converted to kcal per hour based on O2 in liters, the results were 211 kcal per hour for the MC, 236 kcal/hour for the ET, and 288 kcal/hour for the PC. When compared in one-way ANOVA, this was significant at p= 0.000645. This is depicted graphically in Figure 10.

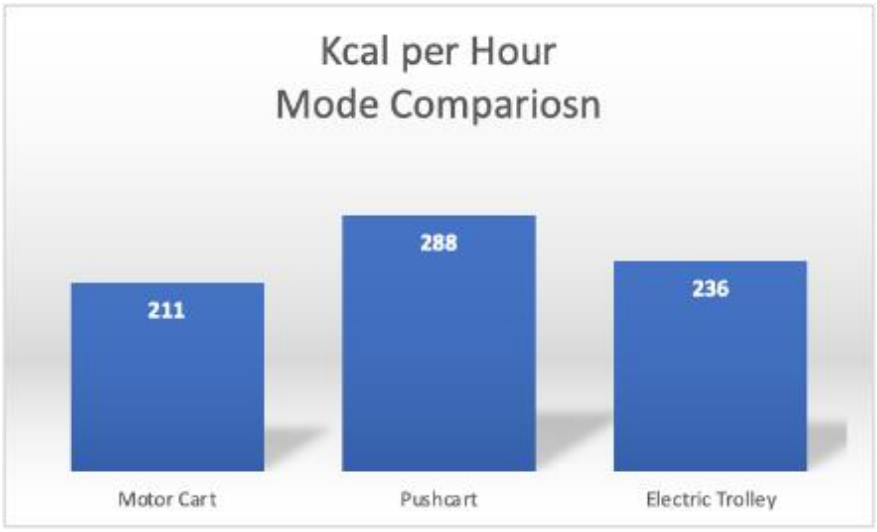

Figure 10 Kcal per Hour Comparison

The average EE for each mode, as expressed in O2 ml/kg/min, was compared to the average VO2 max score (26.36 ml/kg/min for the group) to give an indication of potential fitness benefit. 50% of VO2 Reserve has been considered a nominal threshold for improvement of aerobic fitness levels. In MC play, this was not achieved as the percentage from the golf test was 34% (8.9 versus 26.36). With the ET, this ratio increased to 37% (9.88 versus 26.36). The PC came closest at 46% (12.1 versus 26.36). The investigation also recorded mental focus and score over par compared to the mode of transport/play. The data for each subject comparing those metrics to mode is presented in Table 3.

Table 3 Mental Focus and Score to Par Comparison by Transport/Play

Subject #	MC MF/10	PC MF	ET MF	MC Score to Par	PC Score to Par	ET Score to Par
1	3.25	7.00	8.00	17	12	10
2	6.33	4.66	5.00	6	5	7
3	5.66	5.50	8.00	6	7	4
4	3.33	5.00	5.00	4	4	4
5	4.00	6.00	8.33	5	4	6
6	6.00	7.00	8.00	11	11	9
7	5.00	5.66	7.33	6	5	6
8	4.75	5.20	5.50	21	18	19
9	5.80	6.00	5.50	17	17	16
10	6.00	4.66	5.66	22	21	21
Mean	**5.01**	**5.67**	**6.63**	**11.5**	**10.40**	**10.20**

The ET had the highest mental focus score at 6.63 compared to 10 possible points, followed by the PC at 5.67, with the MC at 5.01. One-way ANOVA measures revealed this result and relationship was significant at p= 0.01482. The summary numbers are presented graphically in Figure 11.

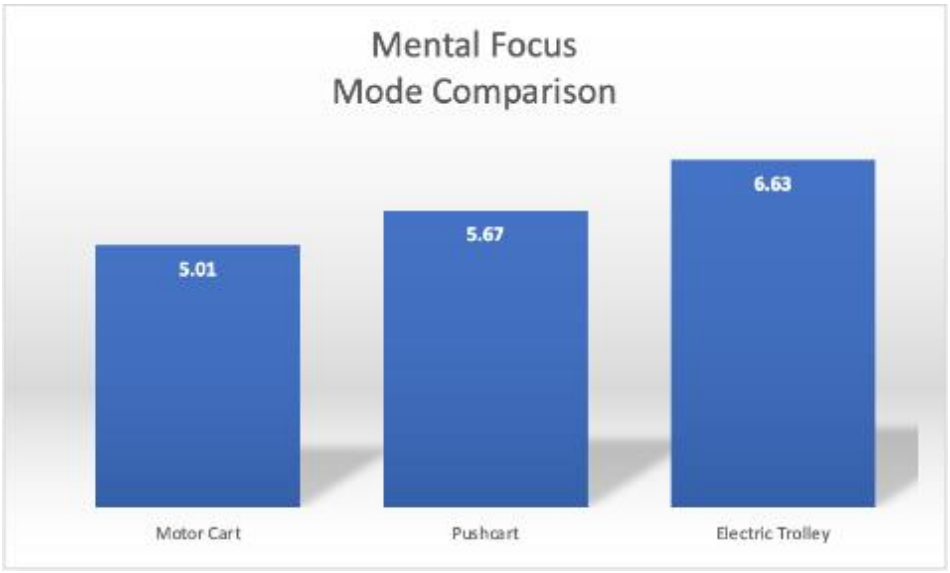

Figure 11 Mental Focus Score Comparison

Analyzed with one-way ANOVA, score over par was outside of the statistically significant relationship yet trended positively at p= 0.1906580. The ET average score was 10.2 strokes over par for the nine holes. The PC was slightly higher at 10.4, while the MC trial scored 11.5 strokes over par. This is graphically depicted in Figure 12.

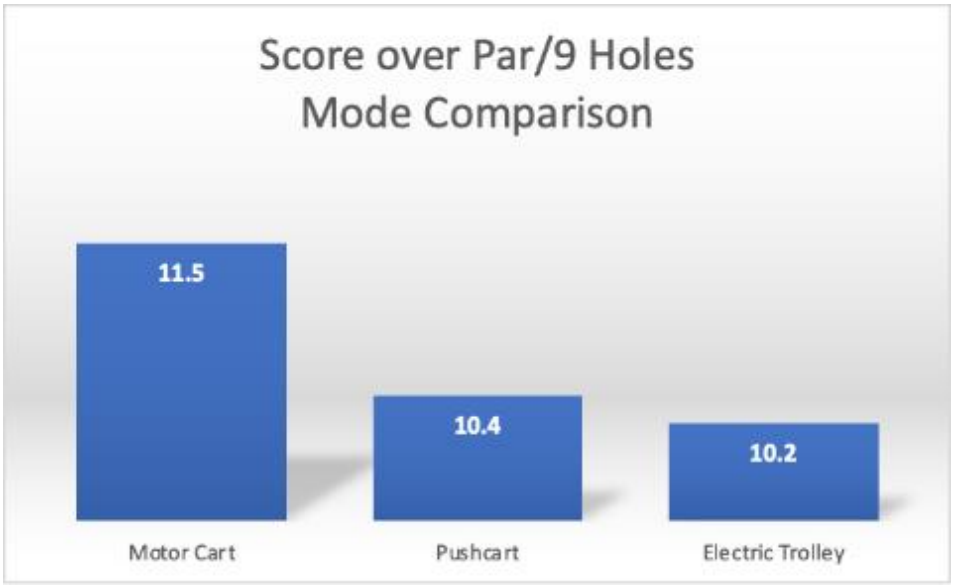

Figure 12 Score over Par by Mode

4. Discussion

The primary conclusion from this study is that walking the golf course in some form qualifies as moderate exercise and a significant addition to daily/weekly energy expenditure resulting in better health [16, 17, 18]. Using the ET is on the borderline of accepted Metabolic Equivalent (MET) levels and total EE for moderate exercise, while the PC is higher in EE in this categorization. When calculated in an EE total for the round, using the mean subject weight of 180 pounds, the average EE for a four-and-a-half-hour round would be 1062 kcal for the ET. A PC resulted in an average kcal expenditure of 1291 kcal for the same period. Both averages demonstrate that golf, when walked as the mode of transport and play, can improve health with possible fitness effects [18], when played regularly as part of an overall movement/exercise regimen.

For those individual's incapable of walking or restricted to using an MC for some reason, there is still benefit as the average result was 949 kcal for an 18-hole round. Furthermore, as more and more investigations focus on adding movement, all three modes have health relevance as they can increase the total movement/EE for the week.

Is golf just walking in terms of EE? The average weight of the subjects was 180 pounds, which equates to 258 kcal for 60 minutes of just walking at a slightly faster than comfortable pace, 2.5 mph. Very few people walk more than 30 minutes in a recreational effort. Reports suggest that during the pandemic, less than only 3.1% of the population walked for 30 minutes, with even less walking for 40 minutes or more per session [19].

Overall usage statistics from the total membership of the Colorado Golf Association indicated that for the 2022 prime season, 20.8% of handicap reported golf rounds were nine holes, amounting to 289,214 rounds. Nine-hole rounds are projected to take an increasing share soon. In playing nine holes with a PC, this total for the research subject average was 648 kcal, 400 kcal more than just walking moderately for an hour. Two significant factors in golf's contribution to health are golfers stay on the course in terms of effective EE far longer than they do in recreational walking and have periods of higher EE than just walking.

Golf is more than just walking in terms of EE and health benefits based upon intensity, duration and primary movement dynamics. These relationships and EE totals are graphically expressed in figure 13 using the mean subject weight for calculations. This compares 60 minutes of recreational walking, nine holes of walking golf using an ET and PC, and 18 holes using an ET and PC.

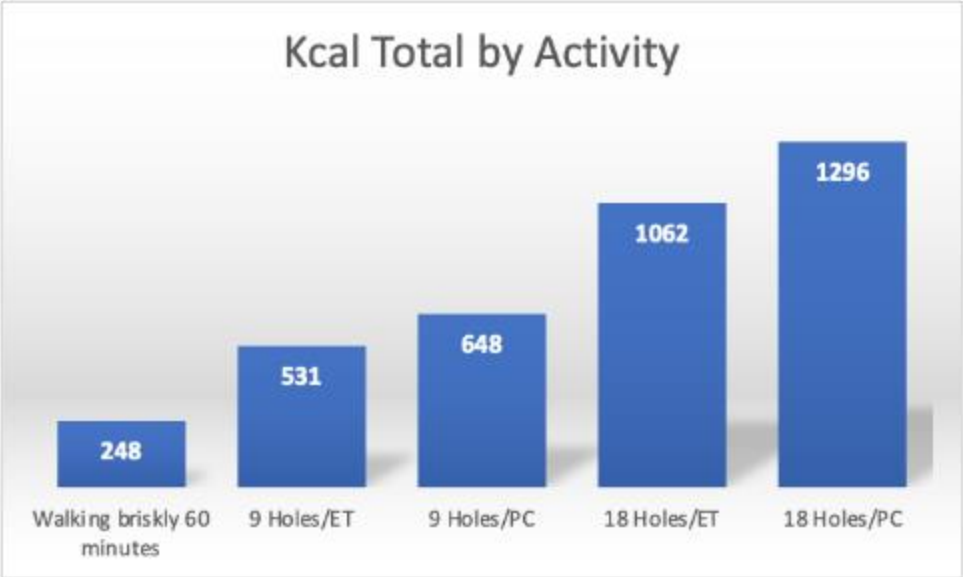

Figure 13 Kcal Total Comparing Walking to Golf Walking Modes

Some relationships exist for all golf courses and modes of transport/play that explain these higher than conjectured EE totals. The golf swing uses energy as a whole-body movement. Most tee boxes and greens are slightly elevated and separated, so there is a walk-up to and down no matter what mode of play the golfer uses. Moreover, even with an MC, most courses limit the proximity the golfer can get to the green or tee box with the MC. Thus, with a MC, the golfer must walk to and from the greens/tee boxes. Those factors add to the energy expenditure total in MC usage. A further note, and not researched, is the resultant EE from the movement of sitting in the MC and then getting up and down for each shot. These factors likely explain the relatively high EE when using an MC relative to walking modes.

Do golfers play better while walking? From this limited investigation, the answer is yes. The mental focus rating and score to par were either statistically significant or strongly trended better for the two walking modes versus the MC. Score to par was significantly better for both the ET and PC compared to the MC. The mental focus rating was slightly better for the ET versus PC compared to the MC. Both forms of walking transport/play resulted in a better performance in actual score compared to the MC. Would these initial observations hold the same pattern for repeated, 18-hole rounds? Future studies should investigate mental focus and score to par with multiple trials over time with multiple sessions per mode.

Further studies should also address how the golfer would perform in this realm if they had significant time to fully adjust to the mode of transport/play before measurement. Golfers have a psychological preference for specific walking modes that are not necessarily tied to exertion or fitness levels. Using the ET had the best mental focus/score combination. However, it likely takes a few rounds for some golfers to adjust fully to the controls and mode of play before even more substantial benefits are realized on the mental side of golf. Furthermore, some golfers appear to like using a PC for various reasons. Would they perform differently after an adjustment period?

EE is modulated in golf by course slope, topography, speed of play, ambient conditions, and, to a degree, the number of strokes, and golf skill level. The golfer's weight combined with aerobic fitness levels is also a factor. As the golfer approaches and exceeds AT [20], where blood lactate can't be cleared while produced, motor skill efficiency and accuracy decline [21, 22, 23]. Individual VO2 max would likely play a role in determining where golf utilizes energy compared to VO2 max and capabilities, and thus, performance is not physiologically impaired.

In applied terms, a golfer with a VO2 max of 30 ml/kg/min will not find a PC EE level of 12.11 ml/kg/min taxing to the point that it interferes with decision-making and shot accuracy. However, a golfer with a lower endurance score, such as 17 ml/kg/min, would find that same 12.11 level a bit taxing both physically and in terms of coordination, especially on the hilly portions where the actual number is above that average and average heart rate climbs to or exceeds AT levels.

Golf is a sport/activity enhanced by aerobic fitness yet may not necessarily develop fitness beyond a marginal level. Two factors come into play with this observation. Golf play is symmetrical in terms of physical requirements, whether actual EE, HR response, or locomotion. For example, golfers will cluster in EE around a mean VO2 in ml/kg/min average for

the specific course. In this regard, EE is a function of weight, the number of swings/shots, and specific movement patterns among other factors. This study demonstrated, even though a small sample, consistency in this regard by the subjects concerning the mode of transport and play. A given course and conditions will have a "baseline" requirement in EE and physical response that is quantifiable in this regard [24, 25].

The fitness level that the golfer enters play with determines whether the activity will result in health benefits, fitness improvement, or both. Those with lower cardiovascular fitness will work at a higher percentage of their capability during a golf round. For this group, golf can have both health and fitness benefits. This training load relationship [26] has increasing relevance with advancing age, and there is an expected decline in aerobic fitness levels, even with training [27, 28, 29]. Simply put, for the less fit and/or older golfer, the physiological load relative to maximum can produce effects in both areas. For the very fit golfer, the benefits from golf in this regard scale back to health enhancement and not fitness improvement. The set EE and physiological metrics of golf do not elevate to the point that they likely influence AT or VO2 Max for those with higher-than-average fitness levels. The effects of golf on energy system fitness are different with age and training status regarding typical and individual fitness profiles.

One factor not measured in the investigation was specific walking/travel patterns and their variability. As golfers hit shots, the ball can go in several directions and different distances, not always in the desired direction to the hole. It is likely the geographical variations in shot direction and specific landing spot affect walking distance, and thus EE. No two golfers hit the same spot with any shot from round to round. Taken in concert, this translates into lower-skill golfers are likely to walk more and expend more energy based on shot pattern and number of strokes. Furthermore, golfers walk different paths concerning ET and PC usage, determined by familiarity and personal transport strategy.

5. Conclusion

Golf with an MC, while not an activity that is considered of moderate intensity, can contribute to daily EE and should be considered a health improvement activity. Golf in the walking modes, using an ET or PC, is moderate intensity exercise that will contribute to health and provides focus and scoring benefits for those with average cardiorespiratory fitness and above. For those with lower-level fitness, it may also prove a fitness development activity.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors report no conflicts of interest.

Statement of ethical approval

This study was conducted in accordance with the Declaration of Helsinki and was approved by the ethics committee of the Colorado Center for Health & Sports Science, Denver, Colorado.

Statement of informed consent

Informed written consent was obtained from each participant after a clear explanation of the study objectives and procedures.

Funding

The CGA provided course usage and support during the study. Walking mode equipment was provided by BatCaddy and Big Max Golf. The contributing entities were aware of project design, yet did not have input on design modifications, results or the final report.

Author Roles

NEW was primarily responsible for research design, testing, on-course measurement and initial data reduction and write up. GMH assisted in research design, write up and final review. BMP contributed to research design, oversaw

course testing and arrangements, and provided editorial content, comments and review for the final version of the report.

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