Metabolic Comparison of Court Sports
Handball's the Best!
...But We Knew That

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This investigation was conducted to forever settle the ongoing debate over which sport provides the best cardio respiratory workout -- handball, the more popular sport of racquetball, or the growing sport of smacquetball.. Smacquetball involves strapping fiberglass handpadd1es to both hands, requiring the ambidexterity of handball but without the associated hand pain.

The subjects who volunteered for this investigation were 10 top finishers in the Open and A divisions of the Utah State Handball Championships. Experienced handball players (as compared to experienced smacquetball or racquetball players) were solicited for this study because handball is the most demanding physically (hands must be toughened) and with respect to motor skills (requires ambidexterity). The average age of the 10 handballers was 40.22 plus or minus 5.58 years, average height was 71.73 plus or minus 3.11 inches (182.19 plus or minus 7.89 cm), and average weight was 183.27 plus or minus 15.33 pounds (83.12 plus or minus 6.95 kg). Percent body fat, tested by underwater weighing, averaged 14.70 plus or minus 6.48 percent.

Methodology

All handballers first reported to the University of Utah Human Performance Lab for a maximal capacity treadmill test. The treadmill protocol involved regular incremental increases in speed and grade from low to maximal intensity until the subject was exhausted and requested to stop (volitional fatigue). Heart rate was determined by electrocardiogram. Oxygen consumption (V02) was assessed by having the subject breathe through a facemask apparatus which had him inhale room air and exhale through a tube leading to metabolic analysis meters. The gas analysis meters computer-assessed the exhaled air with respect to percent oxygen and overall ventilation rate.

The theory behind the oxygen uptake test is as follows: because we know exactly how much oxygen is in the inhaled air (ambient air always contains 20.93 percent oxygen), assessing the percentage of oxygen in the exhaled air will tell us how much oxygen the exercising muscles are consuming. At rest the percent oxygen in the exhaled air is about 17.5 percent for an oxygen difference of 3.43 percent (20.93 - 17.5 percent). During exercise of increasing intensity, the muscle cells consume increasing amounts of oxygen to generate metabolic energy. This in turn makes the percentage of oxygen in the exhaled air decrease to 16.5, 16, 15.5, etc. This occurs while the oxygen percentage in the inhaled air remains the same. Thus, an oxygen content in the exhaled air of 16 percent during moderate intensity exertion will give a difference of 4.93 percent (20.93 percent - 16 percent). This oxygen difference multiplied by overall ventilation rate (total bulk flow of air in and out of the lungs) and several corrections for factors (such as body temperature), allows the computation of V02 during exercise. Oxygen uptake is greatly influenced by body size and is expressed in ml/kg/min (milliliters of oxygen consumed per kilo-gram of body weight per minute) to compare the intensity of different exercises. Expressing V02 in ml/kg/min is important because most sports are weight bearing -- you have to move your body from point A to point B to be successful.

Beginning four days after the max test, players performed 60-minute matches of handball, smacquetball, and racquetball against an opponent of equal skill. Each match was separated by four to seven days, and the order of play of the three sports was randomized. Heart rate was continually recorded using portable heart rate monitors. Each player wore a chest strap containing electrodes and a transmitter which linked heart rate by radio telemetry to a watch worn by the athlete. A micro-computer chip within the watch stored the heart rate results, which were later uploaded into a computer. Oxygen uptake and ventilation rate were assessed by having subjects wear a portable, light weight (5 lb) facemask and backpack system which collected exhaled air. The air was collected in a 60-liter bag hanging from the subject's back and was analyzed for percent oxygen and ventilation rate using the same metabolic system as during the treadmill test. This metabolic backpack apparatus, constructed by Barry B. Shultz, Ph.D. (University of Utah) and Daniel G. Graetzer, Ph.D. (University of Montana), used a modified scuba backpack and a three-way valve which controlled air flow into the bag. Metabolic analyses were recorded every 15 minutes during play. The exact time required to fill the bag with exhaled air during play was recorded very precisely in order to calculate oxygen uptake and ventilation rates per minute later. The velcro-attached bags were then removed and quickly transported from the handball court to the Human Performance Lab where the contents were determined. Determining V02 using the gas analysis system allowed for an exact comparison of the exercise intensity of each of the three sports.' This comparison is much more accurate than simply gauging heart rate, and also determines precisely how many calories are being burned per unit time.

A final parameter, weight loss through sweat, was determined by recording nude weight before and after each 60-minute match using a very sensitive scale (accurate to 10 grams). Heart rate, oxygen uptake, ventilation rate, and weight loss through sweat were then statistically analyzed for comparison across the three sports using repeated-measures analysis of variance (ANOVA) and a Tukey post hoc test.

Results:

Heart rate was significantly higher ($p \geq .001$) during handball (164.08 plus or minus 11.21 bpm) than during either smacquetball (143.73 plus or minus 14.30 bpm) or racquetball (136.60 plus or minus 15.70 bpm). When compared to max heart rate (HRmax) taken during a maximal capacity treadmill test (177.50 plus or minus 8.26 bpm), handball heart rates occurred at 92.44 percent HRmax, smacquetball at 80.97 percent HRmax, and racquetball at 76.96 percent HRmax. Monitoring heart rate alone, however, does not always tell the whole story. This is because heart rate can be elevated beyond what is normally required at a given exercise intensity by one or more factors. These factors include: nervousness, level of conditioning, exercise duration, fatigue from previous activity, environmental heat and humidity, dehydration, drinking caffeine or alcohol, medications, or even the amount of sleep the night before. To get the most accurate assessment of exercise intensity during competition, actual V02 must be assessed.

Oxygen uptake (the average of 4 readings taken every 15 minutes during play) was significantly higher ($p \leq .001$) during handball (30.15 plus or minus 4.43 ml/kg/min) than during racquetball (25.83 plus or minus 4.59 ml/kg/min). Smacquetball V02 (28.02 plus or minus 3.50 ml/kg/ min) was in the middle and did not differ statistically from either the higher handball or lower smacquetball values. When compared to maximal oxygen uptake (V02max) taken during the treadmill test (44.69 plus or minus 6.47 ml/kg/min), handball occurred at 67.46 percent V02max, smacquetball at 62.69 percent V02max, and racquetball at 57.80 percent V02max (see Table 1 'and Figure 2). All three court sports exceeded oxygen uptake (50-85 percent V02max) and heart rate (60-90 percent HRmax) training intensity guidelines established by the American College of Sports Medicine for developing and maintaining cardio respiratory and muscular fitness in healthy adults.

The oxygen uptakes attained during handball can now be compared to other sports and activities. For example: an oxygen uptake of 30.15 ml/kg/min as seen during handball is comparable to running at a 12-minute per mile pace (30.45 ml/kg/min), bicycling at 15 miles per hour (30.8 ml/kg/min), or skipping rope at 80 skips per minute (30.5 ml/kg/ min). It is important to keep in mind that the oxygen uptake values determined during this study are only indicative of aerobic (with oxygen) metabolism .and not anaerobic (without oxygen) metabolism. All three sports utilize both slow twitch (aerobic) and fast twitch (anaerobic) muscle fibers and thus rely on both forms of energy. There is no test available to directly measure the anaerobic calories burned during the short, intense sprints and stop-and-go movements required in handball. The time between rallies also needs to be taken into consideration when comparing caloric burn during intermittent court sports with continuous running or cycling exercise.

Additional information that can be determined from the oxygen uptake data are the number of calories that are burned aerobically per unit time during play. To determine metabolic (caloric) rate, the oxygen uptake value in ml/kg/ min (a value relative to body weight used to compare exercise intensity during different activities) is converted to an oxygen uptake value in liters/min (an absolute value which will be larger in heavier individuals). Approximately 5 calories/ min are burned for every 1 liter/min of oxygen consumed. Therefore, metabolic rate during handball (30.15 ml/kg/min) of a 183.27 pound (83.12 kg) individual; the average weight of subjects in this study -- would amount to 2.50 liters/min. This corresponds to a caloric bum of 12.53 calories/min (2.50 x 5) or 751 calories (12.53 x 60) burned per hour. In comparison, metabolic rate averaged 11.65 calories per minute (699 calories/ hour) during smacquetball and 10.73 calories per minute (644 calories/hour) during racquetball.

The 751 calories burned in one hour of handball is the average caloric bum for the 10 subjects in our study. Metabolic rates, however, are very dependent on body size which ranged from 216 pounds in our heaviest subject to 175.1 pounds in our lightest subject. By examining individual V02 and body weight, our heaviest subject burned 12.6 calories per minute (756 calories/hour); whereas our lightest subject burned 11.97 calories per minute (718 calories/hour).

It is also interesting to use caloric bum measurements to determine if you are exercising enough to lose fat weight. For example: the average metabolic rate of 751 calories/hour burned during handball would be approximately equal to the calories contained in the McDonald's Quarter Pounder (427 calories), French fries (220 calories), and iced tea (110 calories) you had for lunch. The caloric content of various foods can be found in the appendices of most nutrition textbooks or in a computer diet-analysis program. When energy input is equally compensated by energy output, the body is said to be in equal caloric balance. When input exceeds output, the body will gain weight (positive caloric balance); when output exceeds input, the body will lose weight (negative caloric balance). There are 3,500 calories contained in 1 pound of fat. Therefore, to lose one pound of fat weight through handball, you would have to play four hours and 40 minutes. Thus, trying to lose fat weight through exercise alone is not as efficient as most people think. A combination program of exercise and diet is much more effective. When calculating daily/weekly caloric burn from exercise, it is also important to note that oxygen uptake can remain elevated up to six hours post -exercise due to an increase in body temperature.

It is also important to keep in mind that to burn the number of calories as determined in this study, you have to be a competitive handball player in the Open or A divisions. A novice handballer would not be expected to burn as many calories because the length of the rallies would be different, etc. Additional studies are needed to determine oxygen uptake and heart rate during handball, smacquetball, and racquetball play at different levels of competition and also to compare values of competitive racquetball players vs. other competitive racquetball players, etc.

In addition to oxygen uptake (oxygen extraction at the muscle cell level), ventilation rate -was compared across the three sports. Ventilation rate (total bulk flow of air in and out of the lungs) is the product of breath frequency (number of breaths per minute) and tidal volume (air moved per breath). Statistical analysis showed that ventilation rate was significantly higher ($p \leq .05$) during handball (85.95 plus or minus 10.64 liters/min) than during smacquetball (76.41 plus or minus 6.58 liters/min), which in turn was significantly higher than racquetball (70.88 plus or minus 11.18 liters/mm). Ventilation rate data (see Table 1 and Figure 3) showed that players were breathing considerably harder during handball.

Weight loss through sweat was significantly greater ($p \leq .001$) during handball (3.48 plus or minus .89 pounds/hour) than during racquetball (2.53 plus or minus .74 pounds/hour). Smacquetball weight loss (2.99 plus or minus .87 pounds/hour) was in the middle and did not differ statistically from either handball or racquetball (see Table 1). It is important to note that the weight lost during an hour of play in any sport is not due to fat weight loss as most people would like to believe. The higher sweat rate during handball was due to the higher oxygen uptake and chemical reactions of energy production which generated more metabolic heat. The brain's temperature control center in the hypothalamus then stimulated the sweat glands to release more fluid. When sweat evaporates from the skin into the environment, calories of heat are released and the body is cooled. It can be assumed that nearly all lost weight was due to fluid loss which must be replenished in the hours/days following exercise or the body will remain in a dehydrated state. Converting weight loss in pounds to liters of sweat lost, fluid loss in handball was 1.576 plus or minus .403 L/hour, smacquetball was 1.354 plus or minus .399 L/hour, and racquetball was 1.149 plus or minus .334 L/hour. One liter is slightly more than one quart if you are monitoring fluid intake.

Conclusion: handball revealed higher heart rate, oxygen uptake, ventilation rate, and sweat weight loss responses than either smacquetball or racquetball. Stay tuned to future issues of HANDBALL, where more information from the University of Utah handball/ smacquetball/racquetball study will be reported.

Author's Note:

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