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Estimation and Visualization of Paddling Effort for Stand Up Paddle Boarding with a Geographical Information System

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Abstract

In this study, the ‘paddling effort’ is proposed as the total amount of physical activity in Stand up Paddle Boarding (SUP) paddling, which should take into account the wind factor during a course race. The estimation and visualization of the paddling effort were done using a Geographical Information System (GIS) to record and evaluate individual performances or to compare the performances of the participants with each other. To do this, a portable Global Positioning System (GPS) watch with heart rate and cadence monitors was used for recording the location, pitch of paddling, and heart rate of a participant during paddling. The wind vector (speed and direction) was recorded by an anemometer, which was synchronized with the GPS data. Additionally, ‘paddling efficiency,’ which was calculated from the paddling effort and heart rate, was proposed for indicating the total efficiency of paddling activity.

Keywords: Stand up paddle boarding; Paddling effort; Geographical information system; Global positioning system

1. Introduction

Stand up Paddle Boarding (SUP) is a new water sports that was invented in Hawaii in the 1960’s, and it has become popular around the world over the last few years. Figure 1 shows the SUP board that was used in this study.

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This board has a length of 12.6 feet with an inflatable type race board and paddle. Figure 2 shows a paddling scene on flat water. As shown in these figures, the characteristic of a SUP is paddling in a standing position on the board. Therefore, the paddler is required to maintain balance because they need to stand and row with a single blade paddle on an unstable floating board. A SUP can not only be used for a course race, surfing, touring, river rafting and fishing, but other purposes like on-board Yoga for exercise. Many types of boards are available for different purposes, i.e. a long narrow board for racing and a wide board for fitness and recreational riding, including tandem riding for family use. Due to the use of a single blade paddle, the paddler cannot row on both sides of the board simultaneously, which results in a zigzag path. Additionally, a SUP is very sensitive to the wind because the board has a flat bottom, small fin, and a large area for receiving wind due to the standing posture of the paddler.

For SUP paddlers, a Global Positioning System (GPS) is one of the easiest methods for recording SUP activities because there are no pathways on the water except for a few landmarks [1]. Some GPS watches are equipped with a heart rate monitor to record the paddler’s heart rate during exercise, as well as a cadence monitor (Fig.3). To record more precise activities, the wind factor should be taken into account because the SUPs are very sensitive to the wind due to the paddling posture of the paddler, as mentioned above. Furthermore, a Geographical Information System (GIS) is a very useful tool to visualize information along with location, such as GPS data or an address on a digital map from a computer (Fig.4).

The purpose of this study is to propose a recording method for SUP activities with the GPS data using a GIS. Additionally, paddling effort and paddling efficiency are also proposed as indices of paddling activity and performance. Through an analysis of the paddling effort and paddling efficiency, improvements in the personal performance and comparison between paddlers could be achieved.

2. Experiments and calculations

In this study, measurements were made during a SUP trial consisting of about a 15-minute long exercise. Supposing that the board speed vector is a sum of the wind vector and paddling force vector, as shown in Fig.5, the paddling force vector was calculated from the board speed vector calculated using GPS and the wind vector measured using an anemometer. The wind vector, board speed vector, and the paddling force vector were calculated as follows:

- Wind vector
Figure 6 shows the anemometer used in this study. The wind direction and wind speed are recorded as electronic signals with an A/D converter to synchronize with the GPS and heart rate data. Although the anemometer should ideally be placed on the SUP board for precise and correct wind data, it was placed on the beach because the measuring equipment could not be placed on the board. Therefore, the wind of the measuring point was assumed to be same as the wind at the SUP board.

**Board Speed vector**

In Fig. 5, a green arrow shows the board speed vector. The board speed vector was calculated from the GPS data, which provides the location of the paddler on Earth for every second. Because the location data from the GPS was accompanied by time data, the board speed vector data series were calculated from two consecutive points for each recorded data point.

**Paddling Force vector**

In Fig.5, a red arrow shows the paddling force vector. The paddling force vector was calculated from the wind and board speed vectors with a magnification coefficient of $1/50000$ and $1/10000$, respectively, for visualization of the vectors. Although it is apparent that the paddling force vector does not have a physical meaning since the wind and board speed vectors have different units, it is useful for comparing performance at different conditions, especially for varying wind conditions.

**Paddling Effort and Paddling Efficiency**

In this study, Paddling Effort (PE) and Paddling Efficiency were proposed as the total amount of physical activity and activity efficiency. These quantities can be calculated as follows:

\[
PE = \int \text{Paddling Force} \ dt
\]

(1)

\[
HR = \int \text{Heart Rate} \ dt
\]

(2)

\[
\text{Paddling Efficiency} = \frac{PE}{HR}
\]

(3)

where \(PE\) is the integral of the product of the paddling force and time duration and \(HR\) is the integral of the product of the heart rate and time duration, defined as the physical load.

3. Results

Figure 7 shows the recorded data points for the study. In the experimental trial, the SUP paddler traveled around the island counterclockwise from the beach and the wind was constant and incident from the northwest direction.
Therefore, the first half of the round followed the wind and the second half of the round paddled against the wind. Finally, the wind vector, board speed vector, and paddling force vector at every recorded point were represented by location on the map. HR values were also represented with a vertical bar on each individual recorded data point, as shown in Fig. 8. As can be seen in the figure, the paddling force vectors (red arrows) on the right side are bigger than those on the left side because the paddler had to paddle against the wind while travelling on the right side. Additionally, the paddler’s heart rate rose while paddling on the right side (Fig. 9).

Fig. 7 Acquired data points from the GPS watch on the route.

Fig. 8 Wind, board speed, paddling force vectors and heart rate bar, which indicates heart rate value in the vertical direction.

Fig. 9 Board speed and heart rate during recorded period.

4. Conclusions

According to the visualization of this data, a paddler can recognize his/her performance and can compare his/her performance in different wind conditions, as well as with other paddlers using the GIS. Additionally, paddling effort and paddling efficiency is useful for recording and estimating SUP activities.

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References