Effective use of wearable physical monitors and activity trackers for safe stand-up paddle (SUP) instruction.

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Abstract

Stand-up paddle (SUP) is becoming increasingly popular as a water sport requiring balance, strength, and endurance. However, SUP-related accidents and incidents (including fatalities) are on the rise, and the use of wearable body monitors and activity trackers has been proposed to enhance SUP safety. These devices provide real-time feedback on posture, balance, and body movements, allowing instructors to identify potential risks and adjust instruction accordingly. Activity trackers also help people monitor their progress and set realistic goals, contributing to a more effective and enjoyable learning experience. This paper introduces the usefulness of the use of wearable technology in SUP, including fatigue assessment and a system that alerts humans to hazards in the natural environment such as wind and current, and suggests ways in which the device can be used by SUP instructors. In developing this system, we have built a program that can determine the limits of such manoeuvres by acquiring data from actual offshore locations and using statistical methods to analyse the effects of drifting and wind. Based on the results of machine learning, we conducted interviews with experts and people with SUP experience to clarify the usefulness of the program in subsequent risk assessment. The results revealed that manoeuvring limits due to drifting and wind are related to heart rate and SUP behaviour. The findings also revealed the importance of organizing information on various situations, gender, physical fitness, etc. by their profiles to improve accuracy, which will be implemented in the future. In addition, personality and other factors are intervening in the behavioural awareness of participants who receive SUP instruction, and these factors will be examined in the future.

Keywords: maritime, wearable device, human errors

Introduction

SUP (Stand-up Paddle Board Fig. 1) is a water sport where the rider stands on a board and paddles forward and is enjoyed in a variety of directions including racing, surfing, yoga, fishing, river, exercise and foiling. Surfers started it and there are many theories. Initially they were simple, larger versions of surfboards, but more recently they have become more specialised, with improved speed, manoeuvrability, endurance and strength to suit their intended use. They are becoming more popular every year as no special licence is required.

Fig. 1 stand-up paddle (SUP)

On 5 September 2021, one of six people on a SUP led by an instructor was killed in a collision with a fishing boat in Wakasa Bay, about 250 m off Takahama, Fukui Prefecture. The captain of the fishing boat and the instructor were referred to prosecution on suspicion of manslaughter. The sea was calm, and visibility was good on the day of the accident and the instructor was taking photos of the other six people in a row when the accident occurred. Fishing boats are relatively slow and there is little deviation from the course even when the hands are off the boat. Therefore, the accident could have been caused by inattention ahead due to falling asleep or tending to tools. Another possible cause of the accident is that the instructor neglected his duty of care, as the sea was calm and clear at the time of the accident, and he was able to notice surrounding dangers at an early stage.

On 10 August 2021, a man was missing while SUP on Koishigahama Beach, Lake Inawashiro, Aizuwakamatsu City, Fukushima Prefecture. The man had come with five others to teach SUP when he was swept away and went missing and was found dead nine days later. He was not wearing a lifejacket when he was found because of strong winds at the time.

On 9 October 2021, five SUP yoga practitioners were swept away off Chigasaki Fishing Port, Chigasaki City, Kanagawa Prefecture, and were unable to return home.

one of the five was an instructor but had lost contact with the operator. The five were towed away by a passing canoe and were unhurt.

The number of SUP fatalities and injuries has increased in recent years as marine sports have become more popular. (Fig. 2)

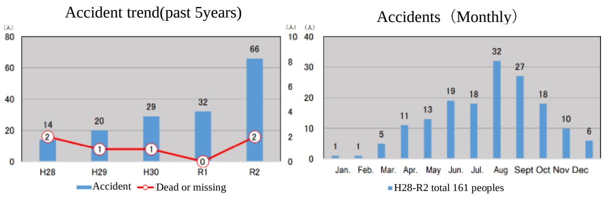

Fig. 2 The number of SUP fatalities and injuries (JCG)

The number of SUP accidents has gradually increased from 14 in 2008 to 66 in 2020. Most of the accidents were non-returnable and were caused by inattention to weather and sea conditions and lack of knowledge and skills. (Fig. 3 and 4)

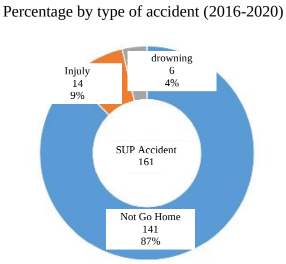

Fig. 3 The number of SUP accidents (JCG)

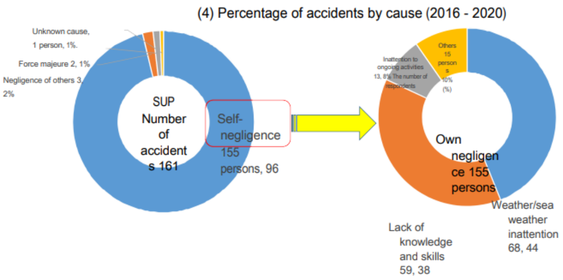

Fig. 4 The number of SUP accidents (JCG)

More than half of the crew had less than one year's experience, and inexperience can be considered a factor in these accidents. (Fig. 5)

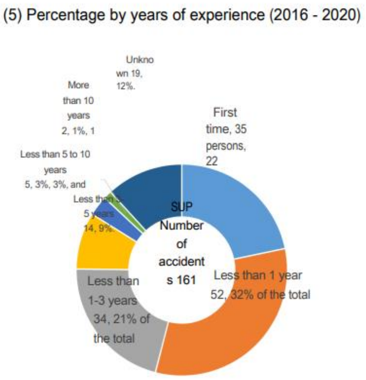

Fig. 5 The number of SUP accidents (JCG)

It can also be seen that SUPs are susceptible to external forces such as weather and sea conditions, as the number of accidents occurring at high wind speeds and high wave heights is high. (Fig. 6)

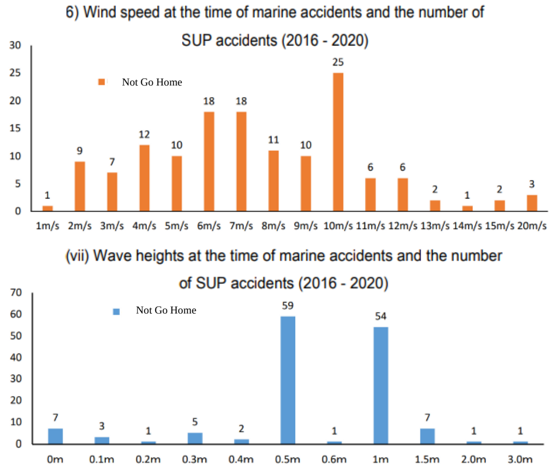

Fig. 6 The number of SUP accidents (JCG)

Although anyone can casually enjoy SUP, it is no exaggeration to say that ocean recreation is a life-threatening activity, as accidents have occurred. Therefore, to protect your life, you must acquire the knowledge to enjoy SUP safely. Knowledge of how to enjoy SUP safely is not difficult to acquire, and includes such things as wearing life-saving equipment such as a lifejacket, learning how to paddle from books and videos before actually doing so, making the decision to stop when the weather is bad, and not overdoing things even if you improve, and only doing what you can do with the skills you have. It is not difficult to enjoy the sport. Other things you need to know include knowledge of weather and sea conditions, board manoeuvrability, and how to take off and land on the shore. After acquiring this knowledge, it is necessary to be able to judge the relationship with other vessels, local rules, and information on the location of the SUP at the time of the SUP.

Materials and Methods or pedagogy

To get an idea of the features of SUP, SUP was carried out in the sea area shown in Fig. 7 using a wearable device.

Fig. 7 Experimental area

To find out the features, a pattern of two days with different tidal conditions and long and short passages was carried out. To perform this pattern, SUP was experienced by six men who were able to paddle the SUP without problems in low wave conditions. They were always fitted with a wearable device. The 'Fitbit sense2' was used as the wearable device. The board used for SUP was a soft board or inflatable board with three fins on the rear part. This has an easy-to-stabilise structure and a straight line for beginners.

Experiments were carried out on 9 and 16 May 2023. The weather was sunny, and the wind speed was rather strong at about 2 m/sec. The tidal currents were opposite on 9 and 16 May but were from offshore towards the harbour (the flow was towards the upper left and lower right according to the graph of results described below).

The validation of the wearable terminals was carried out on land and at sea, in position and speed.

Results and Discussion

In presenting the results, time series data on the wake and speed of each voyage are shown. Each result will also include information on the Dead Reckoning (guess navigation), together with the actual data, to further clarify the forces, including the drifting forces due to currents and the characteristic propulsive forces of the paddles. The calculation method of the Dead Reckoning is based on the mid-latitude navigation calculation method, and the calculated values are the estimated values moving from the trend of 10 seconds ago. The deviation at this time is considered to include the drift force due to the current and the characteristic propulsive force of the paddle, as described earlier.

The long-distance data from 9 May are shown in Experiencer A (Fig. 8,9) and Experiencer B (Fig. 10,11), while the short-distance data are shown in Experiencer C (Fig. 12,13) and Experiencer D (Fig. 14,15). Furthermore, data for the long distance on 16 May are shown for experiencer E (Fig. 16, Fig. 17) and experiencer F (Fig. 18, Fig. 19). Figs. 8, 10, 12, 14, 16 and 18 show the trajectories and Dead Reckoning trajectories. Figs. 9, 11, 13, 15, 17 and 19 show the actual speed and moving average of Velocity (N=10).

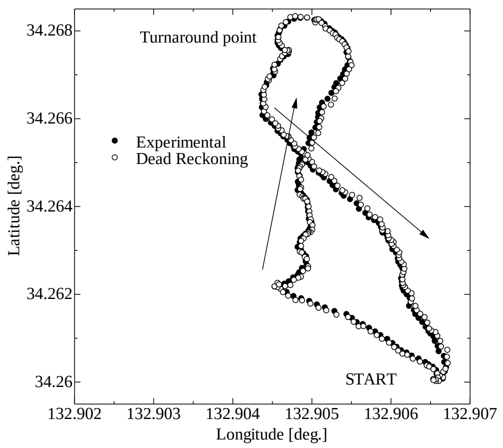

Fig. 8 Trajectory of Experiencer A

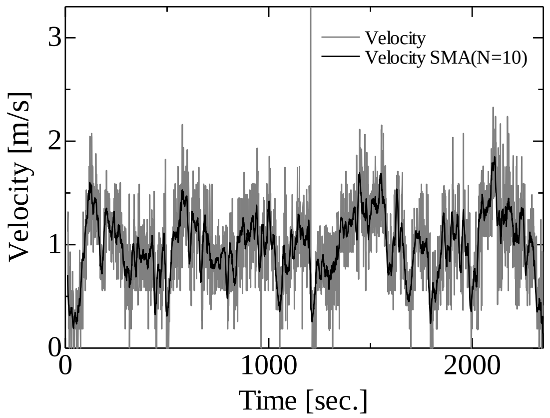

Fig. 9 Time series of velocity of Experiencer A

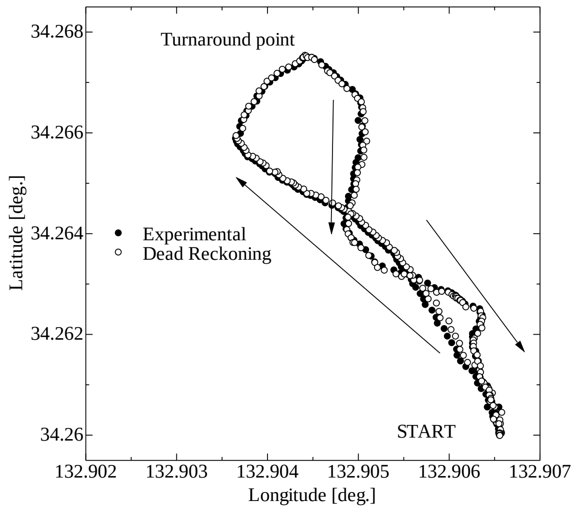

Fig. 10 Trajectory of Experiencer B

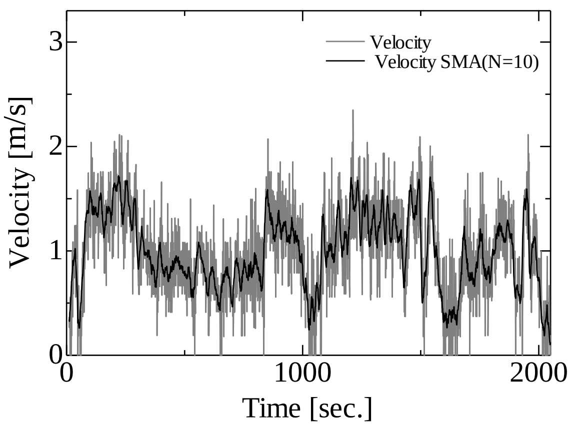

Fig. 11 Time series of velocity of Experiencer B

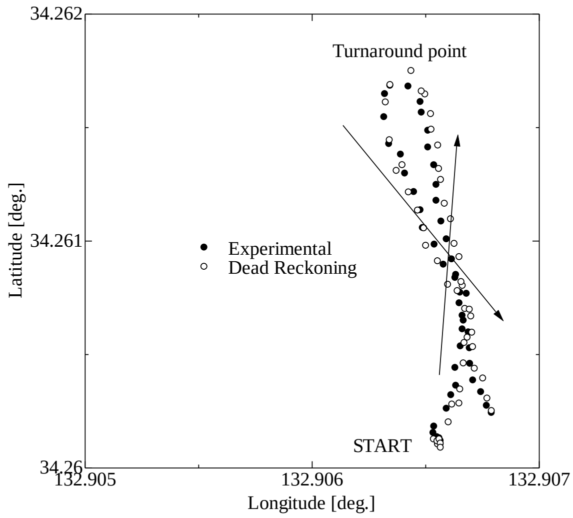

Fig. 12 Trajectory of Experiencer C

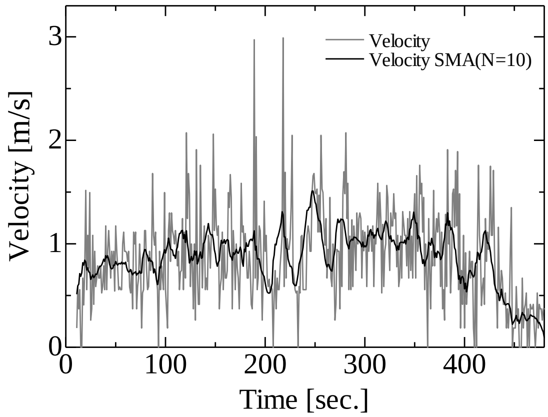

Fig. 13 Time series of velocity of Experiencer C

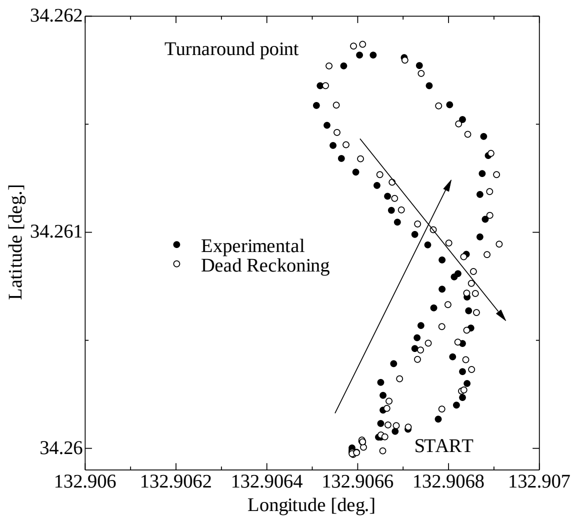

Fig. 14 Trajectory of Experiencer D

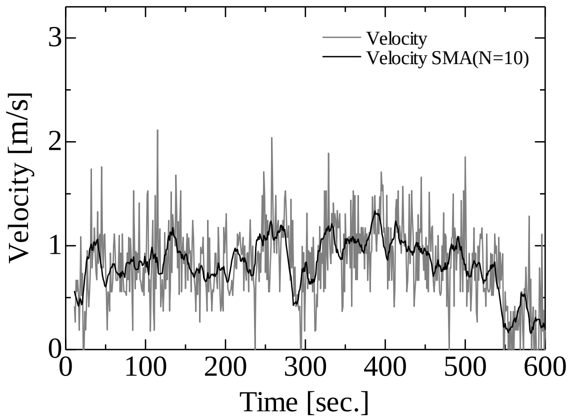

Fig. 15 Time series of velocity of Experiencer D

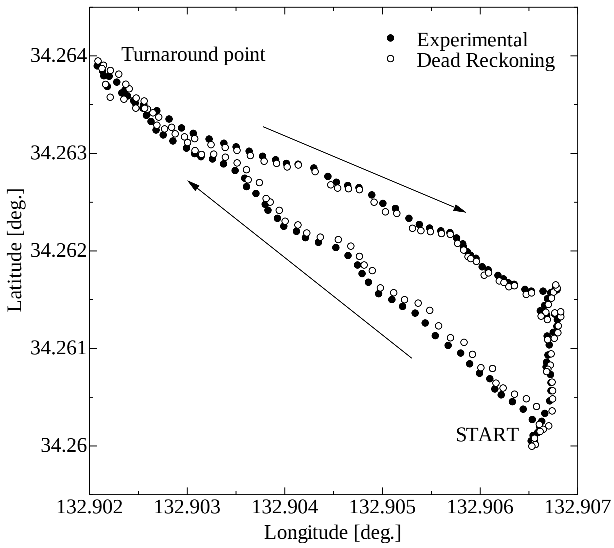

Fig. 16 Trajectory of Experiencer E

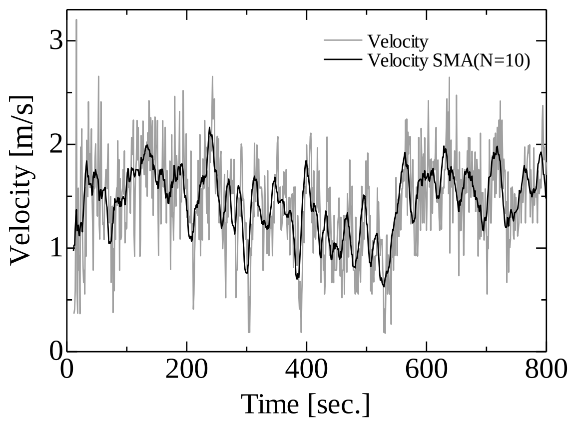

Fig. 17 Time series of velocity of Experiencer E

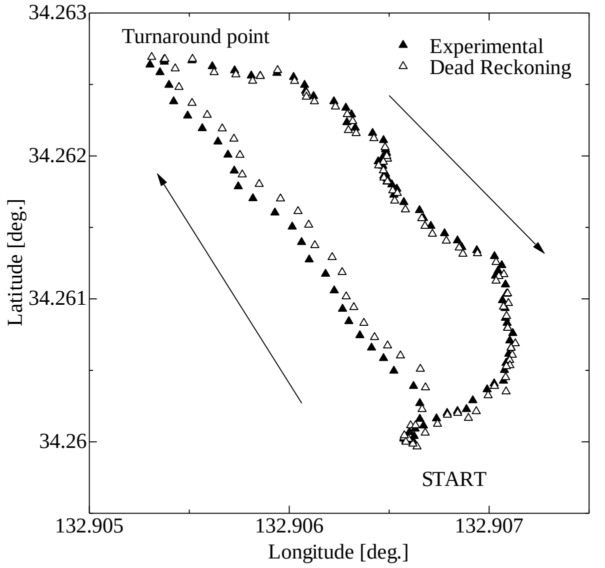

Fig. 18 Trajectory of Experiencer F

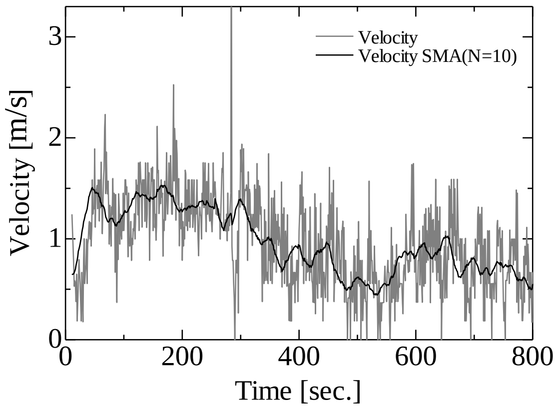

Fig. 19 Time series of velocity of Experiencer F

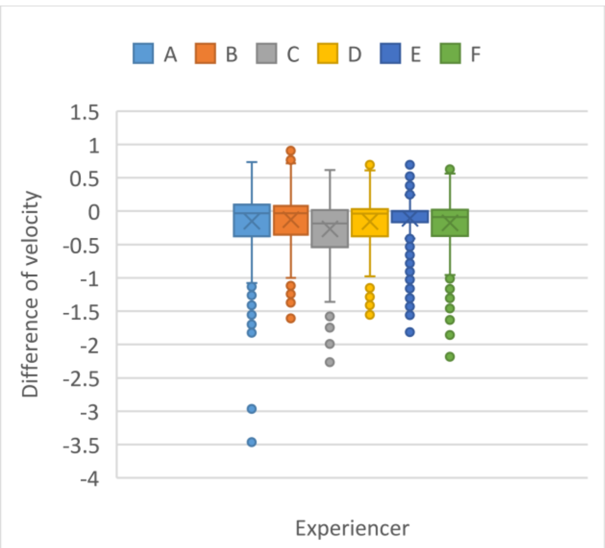

Fig. 20 Box plot of difference of velocity (exp. – D.R.)

The differences between drift and pedal propulsion can be seen in all graphs. This can be further understood broadly as a trend in speed in each experiment. For example, if the board is facing the same direction as the current, the speed increases and thereby the dead reckoning values move away. This may be because the boat may be drifting, which has a significant effect on the current field. In this case, the rowing force is a less relevant situation. Conversely, when the boat is in the opposite direction to the current, the estimated sailing values do not show much difference, and it is considered that the human rowing against it, coupled with the thrust, makes the difference smaller.

Fig. 20 shows a distribution showing the difference between the speeds obtained at the measured and estimated positions of the five individuals. The results show the relationship between drifting and SUP-specific propulsive forces, with zero indicating that these are not acting or are counteracting. The results indicate that when the measured value is higher than the estimated value, the person is more likely to drift, and when the estimated value is smaller than the measured value, the person may be rowing quite hard but not moving forward, and if this situation persists, it is very physically demanding.

Furthermore, the graph shows that the boat is travelling in a zig-zag course, which is not seen in power vessels or canoes. This type of movement is a trajectory unique to SUPs. Such zig-zag trajectories of SUPs are thought to misjudge the apparent relationship from a distant vessel and may lead to collisions.

Conclusions

This study has enabled the use of a wearable device and knowledge of the features of SUPs. In particular, it was considered possible to grasp the characteristics of navigating in a zigzag manner and the fact that drifting and SUP's characteristic paddling propulsion are linked to the trend of the current. Furthermore, it is thought that these monitoring data can be formulated, and that further analysis of heart rate and other data can be carried out using a wearable terminal, making it possible to prevent accidents such as those caused by drifting currents, etc., which make it difficult to return home because of the inability to keep up with one's physical fitness, and thus get lost. This is thought to be possible through the use of wearable terminals.

In the future, it is necessary to further examine whether the combined forces of drifting and SUP's characteristic rowing propulsion are affected by other factors, and to further investigate whether this mechanism is affected by the way of rowing and the centre of gravity.

Reference

Japan Coast Guard (2021), *Incidents of accidents in SUPs*, https://www6.kaiho.mlit.go.jp/watersafety/sup/pdf/01_supaccident.pdf.