Exploring the Data Tracking and Sharing Preferences of Wheelchair Athletes

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ABSTRACT
Sports are increasingly data-driven. Athletes use a variety of physical activity monitors to capture their movements, improve performance, and achieve excellence. To understand how wheelchair athletes want to use and share their activity data, we conducted a study using a prototype wheelchair fitness tracking device, which served as a probe to facilitate discussions. We interviewed 15 wheelchair basketball players about the use of performance data in the context of wheelchair basketball, and we discuss several implications for using and sharing automatically-tracked data. We find that the wheelchair basketball community is less concerned about the privacy of their data, and, in contrast to health data, athletes are motivated by competition. We conclude with a set of design opportunities that leverage digitized performance metrics within wheelchair basketball, which could apply to the broader wheelchair and adaptive athletics community.

Author Keywords
Wheelchair; wheelchair basketball; activity recognition.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous;

INTRODUCTION
To achieve high athletic performance, athletes and coaches need relevant and actionable data. As a result, substantial work has gone into sensing and conveying information regarding athletic performance in mainstream sports (*e.g.*, basketball, football, track & field). In contrast, relatively little work has considered wheelchair sports, which are becoming increasingly popular, yet also present fundamentally different challenges for both sensing and conveying useful data. Wheelchair athletes move differently; they do not take steps [4], unlike athletes in many other sports. As a result, wheelchair athletes care about different aspects of their experience and performance (*e.g.*, "what is my top speed?" or "how active was I during the game?"), even when playing the same sport.

ASSETS '18, October 22–24, 2018, Galway, Ireland

ACM ISBN 978-1-4503-5650-3/18/10…$15.00
https://doi.org/10.1145/3234695.3236353

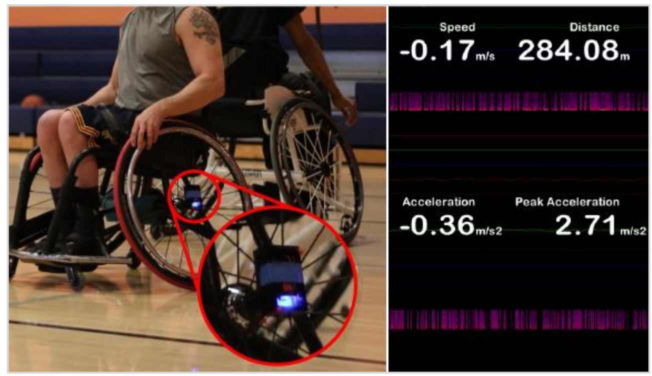

Figure 1. A prototype sensor used to capture real-time motion-based metrics from a wheelchair. We investigated wheelchair basketball athletes' data use and sharing preferences regarding performance tracking. Facilitating access to real-time information, we discuss players' views on the utility of the data, and the implications of sharing this data with teammates, coaches, and other players.

As wheelchair sports have become more popular, new assistive technologies have been developed to improve performance, especially for court sports like basketball, rugby, and tennis. Physical improvements to wheelchairs and better customization for athletes can lead to improved performance [2], with consultancy for elite athletes becoming a growing area of interest for experts *e.g.*, in sports biomechanics [11]. However, much of this information requires extensive processing and is not accessible or useful at the moment. Our aim is to explore the impact of real-time performance data, ultimately to motivate future developments in this area.

While some emphasis has been placed on developing more inclusive fitness devices and communities [4, 21, 13], little is known about the preferences of wheelchair athletes with regard to sharing performance information (*e.g.*, speed, intensity zones, etc.). This is partly due to a lack of available systems that are able to present this information. Although athletes are interested in this information, it can be difficult for athletes to speculate on future use given a lack of experience or reference [5, 6].

In this paper, we explore the implications of automatically tracked performance information on the process and experience of wheelchair basketball. We report on a user study involving 15 wheelchair basketball players who captured performance metrics, such as speed, distance, and acceleration, using a prototype system. We focus on the results of the interview study and a discussion of the implications of real-time, automatically-tracked, performance metrics anchored on data use, athletic preparation, and data sharing.

RELATED WORK

In this section, we discuss related work in fitness tracking and monitoring to provide background for automatically captured data with adaptive recreation and sports. Our work also builds on prior work in tracking, quantification, and sharing of physical activity.

Monitoring and Tracking in Organized Sports

Wearable fitness devices build on the demonstrated motivational potential of pedometers [7, 12] to improve physical activity. Many commercially available fitness devices are able to track information such as step count, calorie expenditure, and overall physical activity by sensing motion from a device. Single sensor devices, such as Morris *et al.*'s Recofit [17] and a growing number of commercially available wearables are able to measure metrics like distance, calories, motion, sleep duration and quality, heartrate, skin temperature, and more. The active reflection on this data has been central to movements like the Quantified Self [19] and have fueled waves of technologically enhanced fitness, competition, and social connection [23, 28]. Our research continues to support progress toward improving the role of fitness devices to support wheelchair basketball players.

Effectively managing the health of the athletes is essential to success in competitive team sports. High-performance athletes are routinely asked to push the boundaries of their abilities. Sustained activity at such high levels increases the risks of declines, but deep understanding of one's performance can enable strategy development to maintain higher overall performance for longer periods. Improper management of the demands placed on an athlete can lead to fatigue and injury. Several strategies have been employed for stamina and fatigue management in competitive sports including detailed analytics, constant assessment, and multi-faceted interventions including detailed exercise programs, nutrition regimens, mental training, and rest [16, 20, 22]. Technology has seen an increasing role in developing, communicating, and supporting physiological awareness and learning. Our aim is to support the management and use of objective measurements captured from sensors to support new performance insight, reflection, and sharing.

Wheelchair Tracking and Logging

The current state-of-the-art for these assistive devices uses miniaturized data loggers in order to collect and store motion information over long periods of time (*e.g.*, months). This information can be valuable to practitioners, including coaches and trainers, to modify future training procedures [15]. In the context of wheelchair court sports, prior research [6, 10, 13, 25, 27] has identified players and practitioners interests in objective measures of speed, distance, and acceleration for wheelchair athletes. However, much of it requires offline processing and is not immediately available. Thus, our goal is to support real time feedback on these metrics.

Miniaturized data loggers have been used previously with multiple sensing approaches, including reed switches [25, 27], accelerometers, gyroscopes [10], and indoor RF positioning systems [15]. While GPS-based and indoor positioning approaches have also been used to sense sport related activities [3, 8, 24], greater accuracies have been achieved by directly sensing activities through wheelchair-attached sensing [10, 15, 25, 27].

Sharing of Automatically Tracked Data

Sharing health data has been shown to offer benefits to motivation, reflection, and behavior change [26, 9]. Other studies have recommended the types of data that should be shared and with whom [18]. Concerns over privacy and feelings of self-consciousness can arise from the sharing of this data [9] as well as concerns of misuse, especially with respect to health data [1]. People with mobility impairments may be interested in sharing health and fitness data with other users with similar conditions or within communities with shared interests [4, 13]. Additionally, Malu and Findlater [14] explored the sharing of fitness and health data among people with mobility impairments. They identified important challenges and opportunities that arise from sharing this data with peers and clinicians. We extend this work by considering performance related information rather than physical activity for health and wellness.

ENGAGING WHEELCHAIR BASKETBALL PLAYERS

We engaged wheelchair basketball players in two settings: *1)* a local wheelchair basketball team practice, and *2)* at the 2018 National Wheelchair Basketball Tournament (NWBT). During the practice, one player used prototype sensors for tracking. During the NWBT, we had a demonstration booth where athletes were invited to use the same prototype system to automatically capture data from their wheelchair. The system used multiple sensors to capture the speed, acceleration, and distance travelled by the wheelchair. This information was displayed to the user in real-time using a large 42" display. Participant profiles and the interview structure are presented below.

Participants

We recruited 15 wheelchair basketball players to participate in our study. This included 1 female player and 3 players who also coached. The mean age for participants was 33 (std. dev. = 10.98) with a range of experience from 1 to 35 years. At least one player from each of the eight classification levels (1.0 to 4.5) was represented [6].

PID	Age	Gender	Experience	Class	Role
P1	58	M	35	4.0	P*
P2	24	M	2	3.5	P
P3	26	M	13	4.0	P/C
P4	36	M	25	1.0	P/C*
P5	35	M	18	1.0	P/C
P6	29	M	5	4.5	P
P7	35	M	3	3.5	P
P8	42	M	3	--	P*
P9	47	M	20	2.0	P
P10	19	F	1	2.0	P
P11	37	M	25	2.5	P
P12	20	M	3	1.5	P
P13	32	M	22	4.0	P
P14	22	M	7	3.5	P
P15	--	M	10	2.0	P

Table 1. Demographics of Participants in interview study. Role is either P for player or C for Coach, * - Retired

Interview Format

Each session was approximately 25 minutes and consisted of two parts: A demonstration and an interview.

Demonstration

We first demonstrated the collection of automatically captured data using prototype sensors, consisting primarily of a WiFi-enabled microcontroller and 9-axis IMU. Participants were presented with an interface that numerically represented the tracked metrics including speed, acceleration, distance travelled, peak speed, and peak acceleration (Figure 1). The sensors stream data and update the values shown in the interface in real time.

Interview

Due to the nature of collecting data at the National Wheelchair Basketball Tournament, we aimed to keep interactions with players short and direct. Interviews were semi-structured and focused on three topics:

1. How useful is this automatically captured data?
2. How do you think this data could/would be used by an individual player? What about for a coach?
3. Who do you think should have primary control over the performance data? The player or the team (coach)?

Participants were also asked to fill out a questionnaire with background information, demographics, experience with wheelchair basketball, and information about the wheelchair that they used (Table 1).

Analysis

During each demonstration and interview session, the researchers took notes on the interactions and captured quotes from participants. The authors adopted a theoretical approach to thematic analysis of these field notes. The analysis focused on the three questions listed in the previous section regarding usefulness, use cases for players vs. coaches, and ownership.

FINDINGS

Participants described how the use of real-time performance data and metrics would be a useful and novel addition to the wheelchair basketball experience. Players were excited about the ability to use real-time data to augment their training processes and game performance. They described how important the immediacy of the data can be as well as the ability to review performance over time. In this section, we discuss players and coaches perceived usefulness of automatically sensed data for themselves, and with teams.

P3 described how sensor-based measurement can help teams with skill-training and progress evaluation:

"This would be really useful at universities. They can work on skills training, and they practice all the time. Real-time information helps a bit more than what we have now. For instance, right now assessments take place more at the beginning of the season and end of the season. With this you could have that assessment throughout." -P3

Teams can use the data from sensors as an important motivator for their players. The real-time feedback can be used to provide feedback in-the-moment:

"Having something like this to log the data would be really useful so that you could give a player feedback on something they did while it is still fresh. Instead of asking to remember this one time either in the last game or earlier in the season." – P3

P14 described how a tool like this could be used to improve, individually, by comparing with other athletes:

"At this point, sports like biking and stuff will tell you 'this is how fast Lance Armstrong was at this part of the tour de France.' If you want to be like Lance Armstrong, this is where you need to be or where you need to improve." – P14

Tools and data that rely on automatically gathered information can reduce the burden on players and coaches. Thus, giving them more time to focus on strategies to overcome their weaknesses and work toward improving performance, allowing the transition from subjective feelings to objective data:

"As for teams competing with each other I think you already kind of know what to expect from intuition, but this would add some objectivity to confirm those intuitions or see where you are versus a team or you have less experience playing with." – P14

DISCUSSION

Sports are increasingly utilizing detailed analytics. It is important to consider the impacts of quantification in various situations. While many similarities exist between health data and performance data, there are some important differences in motivation which should be considered. We discuss implications for the design and use of performance monitoring technologies based on our experiences with wheelchair basketball.

Implications for Data Use During Training and Practice

The athletic community is very similar to the general population of people quantifying their activities. They have developed strategies and use cases for the data. In addition, performance in athletics often takes into consideration much shorter time frames and with more detail. For instance, counting how many steps a person takes in a day might be considered useful to estimate "how active you are throughout a day". For a wheelchair basketball player, how "active you are" more likely refers to how much time you spend battling for position on the court vs. the amount of time you spend sitting still, accelerations in quick bursts vs the time you spend coasting around the court. Players mentioned the potential impacts of having objective data not only on their *level of performance* but also how well a player can *maintain* that performance.

"I see this as more a tool for endurance… are my players fast enough to keep up with the other team, consistently, or do we need to develop other strategies?" – P3

This is consistent with players motivations to understand how to manage fatigue and stamina to maintain high performance [6].

Competition as Motivation

Another key implication for using objective data is its potential to facilitate competition. Since sports are inherently competitive, this can be a strong motivator:

"I just think it's really cool. I know I'm fast, but I want to know how fast. This is really fun to see it like that." – P7

While conducting our study at the NWBT, athletes wanted to be the "best". P13 asked what the fastest speed we had encountered had been so he could compete.

"This is really cool, I've got to get my guys down here. I'm gonna get that top speed. I just lost my game so if I can win at this, I'll feel good." – P13

P13, a high-performance athlete and a former member of U.S. National Team described how the environment of wheelchair basketball and the competitive nature of these athletes would definitely be motivating.

Immediacy vs Post-Hoc Review

We found that players were more interested in using real-time data during practices than *during* actual games, in favor of post-hoc review:

"The in-the-moment feedback is really useful. I think game related stuff is more useful post-game. Actual, in-the-moment is really useful in practice." – P10

P1 described how current game data is handled through video review and analysis:

"A lot of what you have right now is video. So, people will go through the videos and talk to players about their performance so if you had something like this that could integrate with video that would be really cool. Some of the video tools will let you do motion analysis now too so you could use both." – P1

Conversations with coaches during our demonstrations indicated that they can spend long hours analyzing and annotating video data to review with their players. In many cases, there is enough time to analyze the previous performance, but this often results in tradeoffs between preparation and review. The less time you need to spend reviewing, the more time you can focus on the next challenge or strategizing the adjustments that need to be made among the team or with individual players.

Considerations for Data Ownership and Sharing

For the most part, players were not concerned with sharing their performance data. Multiple players discussed the potential to create a shared resource or database for performance: *"a scouting database or something, especially for like the kids. You could put up the stats and be able to see you know how you or how other people compare."* – P9.

Players expressed an interest in sharing ownership of the data and the devices with teams but see the usefulness for their individual purposes:

"In terms of future use, I would think personally that I'd want to own the device and the data. Like, I think the data would be really useful for teams, especially for college, but as an individual I'd want it, to see how I'm doing." -P3

Players acknowledged that some control over the data should belong to them, but may be less important in different situations:

"So, for like a scouting situation it would be really important for you to control the data that gets uploaded. But with the team or the coaches not as much." -P10

P14 added that it really depends on the interpersonal relationship between coach and player:

"What a coach sees about the player really depends on the player-coach relationship. Personally, I don't care if my coach sees my bad workout days. I mean even without something like this I could lie on my workout sheets if I wanted to. I think the data is a good conversation tool."

However other players seem to agree for the most part that a team-based tool rather than a device for individual players might be better:

"I would think the data could be more team-based more than individual just because it's probably more useful there and just makes more sense." -P10

P6 also stated that the team should control the devices and data but for more practical reasons:

"I think you would use it more in a team setting. I think you'd have fewer players using something like this. But it depends on the setup steps, and like doing all the math, it's got to be simple. How do I put it on? Do the calculations? etc., it can be a bit intimidating. I just think less players are going to feel like investing the time on their own." – P6

Previous research has shown that sharing data with peers should be an engaging experience rather than just passively collecting and viewing your own data [14]. While others have identified potentially negative impacts of sharing activity data, it is important to also consider the purposes of sharing. From a health perspective, sharing, as opposed to comparing, with other people is often discouraged as the uniqueness of situations can be overlooked leading to negative outcomes. However, among our participants, comparison with other players (in the context of sports) is a centrally desirable feature. More research is needed, with working systems in the field, to determine whether these negative outcomes persist with regard to performance data.

Community as Motivation to Share and Excel

Wheelchair basketball, by design, is an inclusive sport that incorporates functional ability into balanced competition. Players' abilities can be augmented and extended by their wheelchairs, allowing them to reach their full potential. Participation in the game is highly inspiring, creating an environment that spawns a virtuous cycle where players at all levels (from amateurs to Paralympians) strive for excellence. Thus, it is not surprising that everyone in the wheelchair basketball community is highly supportive of each other, despite being in a competition. This is exemplified by the following quote:

"They've gotten so much from this sport that I don't think anyone would be unwilling to give back." -P14

P14 elaborates by saying that as a collegiate wheelchair basketball athlete, he would be willing to share his data because he knows it can inspire future players. Since wheelchair basketball is a "game of inches" (*i.e.*, being quicker wins games), knowing how fast *e.g.*, Steve Serio (Team USA) accelerates or makes turns can serve as a baseline for future athletes to strive for. The balance between inspiration and competition can be a powerful motivator for new athletes and the future aim of this research is to support developing pathways to achieve excellence through data.

LIMITATIONS

The strength of providing a reference point for using a device as a probe can also be a limitation as it may restrict the participants imagination to the current solution. We acknowledge the potential limitation that arises from using a working device as a probe, however we feel that our demonstration was presented as an adaptable sensing solution rather than a completed system. Participants were able to conceptualize variations of the system to capture the information needed by wheelchair athletes.

We elected to use a working system for our study to expedite conversations beyond a lack of reference technology. Prior work has shown that people have difficulties imagining a future state without such references [5]. While many parallels can be drawn to other, traditionally able-bodied sports, there are substantial differences between the ways that wheelchair athletes move; even their visions of the future may be limited by perceptions of possibilities in able-bodied sports. Like Malu *et al.* [14], our data is based on perception of a future system based on an interactive demonstration and not based on actual use of the system, in context.

DESIGN OPPORTUNITIES AND FUTURE WORK

Based on our findings, we identify the following design opportunities for future work to explore within both the wheelchair basketball and broader wheelchair and adaptive athletics community:

- Support selective sharing of performance data by players. This is consistent with [14].
- Supporting comparisons between players with similar abilities, classifications, or in similar regions *e.g. How can I compare to other guards? or other 1.0 players?*
- Support integration of sensor data with existing performance reviews and assessment. This is similar to sharing information with clinicians [14].
- Supporting goal setting and casual comparison between peers and/or elite athletes. Example: *"If Steve Serio's top speed is 10 mph, I want to go 11."*
- Extending real-time data capture to other sports like racing, which are more individualized.

CONCLUSION

This research explores the use and sharing of automatically captured physical activity and performance data regarding wheelchair athletes, specifically wheelchair basketball players. In this paper, we described a study involving 15 wheelchair basketball players who used a prototype activity tracking device to capture performance metrics including speed, acceleration, and distance travelled. We presented the results of an interactive demonstration and interview study focusing on the usefulness of performance metrics with respect to players and coaches. We also discussed implications of using and sharing this data with regard to different training and competitive situations. Our results extend and contrast with existing research focusing on sharing physical activity in health-centric applications.

As sports continue to shift toward analytics-driven progress, it is important to understand that as P14 says: *"I don't think of this as an 'IF we can get this data.' I think something like this moves us closer to where we will just BE, eventually. So, it's more of a WHEN, not an IF."* It is important for researchers and practitioners to capitalize on opportunities to understand and develop thoughtful systems as they are integrated into practice. We identified opportunities to further develop fitness related technologies and systems for the future of inclusive, technology-driven sports.

ACKNOWLEDGMENTS

We thank all the participants, Per4Max Medical, and the National Wheelchair Basketball Association (NWBA) for their support of our work. Aspects of this work were also developed under a grant from the National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR grant number 90DP0061).

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