Using Speculative Design to Understand Preferred Futures for the Design and Use of Tracking Data in U.S. College Sport Teams

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US college sports teams are increasingly adopting personal data technologies, such as wearable sensors, with a goal of improving individual and team performance as well as individual safety. These tools can also reinforce the power that coaches hold over student-athletes and compromise student-athletes' needs for privacy and agency. To investigate preferred, and anti-preferred, approaches for navigating this complex sociotechnical challenge, we used a speculative design approach in which student athletes and technology design students developed three videos that portray tensions between student-athletes and coaches around the use of sports tracking technologies. We then shared these videos with 15 participants including student-athletes, coaches, and designers. Drawing on the perspectives of student-athletes, team staff, and designers embedded in the videos and expressed in reaction to the videos, we describe preferences for boundaries on tracking and sharing, how tracking data represent athletes, and for data practices. We also propose design requirements and recommendations for use to better align tracking technologies with these preferences.

CCS Concepts: • **Human-centered computing** → **Collaborative and social computing theory, concepts and paradigms**; **Empirical studies in collaborative and social computing**;

Additional Key Words and Phrases: sports, personal data, data-supported collaboration, power, speculative design, research through design

ACM Reference Format:
Samantha Kolovson, Samuel So, and Sean A. Munson. 2024. Using Speculative Design to Understand Preferred Futures for the Design and Use of Tracking Data in U.S. College Sport Teams. *Proc. ACM Hum.-Comput. Interact.* 8, CSCW1, Article 189 (April 2024), 35 pages. https://doi.org/10.1145/3641028

1 INTRODUCTION

Technologies that measure, aggregate, and report on personal data are increasingly being adopted in collaborative settings, such as for use among patients and clinicians [13, 15, 73], among families [18, 50, 59], and within workplaces or other organizations [14, 37]. Such uses of personal data can support collaboration, coordination, and shared awareness, but they also come with potential harms, including surveillance and privacy violations as well as subverting individual autonomy and agency [5, 17, 43].

One group setting where personal tracking technologies and data are being rapidly adopted is team sport. Previous research emphasizes the potential of sport tracking technologies to support both team and individual athlete goals [16, 43, 62]. However, this work also shows that simply

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2573-0142/2024/4-ART189 $15.00
https://doi.org/10.1145/3641028

adopting tools designed for individual use in team settings is insufficient to achieve the potential benefits, as such tools are not designed to support coordination and collaboration among athletes and coaches or other team staff [43]. Further, tools designed to increase the visibility of data across a team are often extractive, which in turn introduces other challenges, such as increased surveillance and magnification of the coaches and staff's power over athletes while diminishing athlete's agency and control over data about their own bodies [17, 43].

The rapid design and adoption of tracking technologies among sports teams presents an opportunity to disrupt current social dynamics on teams and reimagine ways to design tracking technologies that support the needs of multiple roles in the pursuit of team goals while also supporting individual goals and autonomy. Achieving these outcomes will require redefining the norms of how data are collected and used on teams, rather than using technology to reproduce or extend extractive and dis-empowering team dynamics. How can sport tracking technologies facilitate communication and collaboration around athlete data? How can they support athletes in better knowing their own bodies and support them in working with team staff to make decisions that benefit them and the team?

In this research, we use speculative design to explore different possible futures for tracking among sports teams and to then elicit athlete, team staff, and designer attitudes about these possible futures. Speculative design supports us in putting forward possibilities for the design and use of sports tracking technologies, reflecting on the ways in which they do or do not balance the needs and goals of athletes and coaches, and then identifying preferable futures (Voros, 2003) through that reflection and discussion. For our specific setting, we selected team sports in US college athletics, which are regulated by rules set forth by the National Collegiate Athletics Association (NCAA) in an attempt to balance the student and athlete roles of student-athletes. However, the ways in which these regulations interact with sports tracking technologies have ambiguities that make it an opportune time to articulate preferred and not preferred features that can guide the design and use of tracking technologies.

To investigate our research question—***What are the preferred futures for the design and use of tracking technologies in college sports teams?***—teams of researchers, student-athletes, and technology design students created three speculative videos depicting different future scenarios for tracking among college sports teams. We then showed these videos to four student-athletes, five current or former team staff, and six health or wearable designers (three of whom were also former student-athletes) in individual and group interviews to gather their reactions to the scenarios and their articulations of preferred–and non-preferred–futures.

We contribute:

(1) Three speculative artifacts with embedded knowledge representing preferred and non-preferred futures of the design and use of sports tracking technologies by college sports teams. Plus, knowledge of additional preferences based on analysis of student-athlete, staff, and designer reactions to these artifacts.
(2) Design requirements for sports tracking technologies intended to be used in a team setting, including customization to team norms and rules, translucent data representations for team staff, transparency for athletes, and providing scaffolding for interpretation of tracking data.
(3) Recommendations for the use of student-athlete tracking data, including setting expectations, engaging specialists, using tracking data alongside information that better represents context and always in communication with athletes, and developing NCAA policies that constrain what tracking tools teams can adopt and how they can use them.

Though our work is grounded in the context of US college athletics, past research has noted that, at a high level, the dynamics present in this context—a combination of individual and collective

goals that sometimes align and diverge and the potential for power asymmetries and the data to reveal information of consequence—can inform a broad range of contexts [43]. Many such settings are adopting tracking technologies and facing similar challenges, and we believe that the principles for design and use here, as well as our methods, may support other kinds of organizations in the appropriate adoption of tracking technologies.

2 RELATED WORK

Many people have adopted wearables and tracking apps for greater awareness of their behaviors and the factors that affect them [26], testing potential relationships between behaviors or contextual factors and outcomes [38], and tuning their behaviors to align with goals [26]. Though researchers, technology designers, and the public at large have noted opportunities associated with personal informatics, they have also noted that designs do not always support people's goals [25, 34, 44] and some common design patterns in personal informatics, such as calorie tracking, can cause harm to many users even as they are beneficial for others [19]. Similarly, though tracking can be an important tool for understanding and managing many chronic health conditions, the act of tracking can also be a negative emotional experience and demanding of people's time [3].

Though this field is known as *personal informatics*—reflecting the personal and often sensitive nature of the data collected—this term can mask that many of the uses are actually collaborative, encouraged by one person to another, or imposed on someone. Further, some uses can be exploitative [48]. A family may use personal informatics tools to pursue a shared fitness goal [59] or to coordinate care for a family member managing a chronic illness [55]. People managing a chronic condition or pursuing a health goal may use the data to access better advice and support from their medical team [13, 15, 73]. And companies use personal data to evaluate, coordinate, and control their employees (or contract workers they will not even acknowledge as employees) [69]. Even when these uses are well-intended, the sharing of data can lead to privacy violations, exploitation, and other abuses [1, 14, 69].

Our work draws most on past research that has described how and why individual athletes and teams are adopting sports tracking technologies, as well as some of the breakdowns that occur when they do [5, 17, 43]. In particular, we focus on the ways that sports tracking technologies tools can reinforce or challenge existing power dynamics, including heightening power asymmetries within teams.

2.1 Inter-Personal Informatics in Sports and Teams

Individuals and teams are adopting sports tracking technologies to improve their performance through understanding and changing behavior [40, 46, 63, 74, 80], prevent injury [20, 23, 30, 31, 31], and optimize training [21, 46, 68, 71]. Though adoption at all levels of sport is concerning, we are concerned with college teams' use of these technologies and their data [5, 27, 43]. Particularly, how the current design and use of sports tracking technologies by college teams can reduce student-athlete agency and reinforce the coach's power over student-athletes, creating more opportunities for potential intended or unintended abuses of data [5, 17, 43].

The potential to improve performance is a powerful motivator for athletes and teams using wearable technology because the main goal for athletes and teams is usually success—winning competitions and/or reaching their potential, both in the short term and long-term—and they can be more successful if they can improve their performance and wellbeing [36, 61, 72].

However, as with other use cases, athletes experience many challenges to making effective use of data from wearables and other sports tracking tools. The main challenge is a lack of knowledge or resources to understand, analyze, or find actionable insights from the data. For example, the

technology and its data alone do not provide direction for training, coaching expertise plus additional sport or analytics knowledge is needed [16, 62].

Using wearable data among and about teams magnifies existing challenges and adds new ones. Athletes often rely on their coaches to interpret their performance and help them improve [16, 62], sometimes because they do not want to taint their felt experience of their sport [62, 78]. However, college coaches may lack the time or knowledge to interpret individual data or appropriately manage the data from the whole team [16, 43]. They also may lack the resources to hire someone to help analyze the team's data and ensure that it is handled securely [43].

Using data within teams also adds new socio-technical problems due to social dynamics. There is an opportunity for shared data to support athlete-coach communication [49, 62], but data can just as easily be another tool of a coach's power. Professional and college athletes described coaches as gatekeepers to the data: collecting, analyzing, and changing workouts based on the data all without the athletes ever seeing it [43, 62].

The goals that coaches and staff have—improving performance, protecting athlete wellbeing—are worthwhile and even possible through using tracking data. However, teams, specifically coaches and staff, are adopting tracking technologies and forging ahead, trying to use the technology to make more data-driven decisions about their athletes and teams, even as they lack the ability to collect the right data, to make valid inferences from it, or to develop appropriate practices around privacy [32, 43]. Further, privacy concerns and a desire to present a better front to their coach can lead athletes to distort their data or obfuscate it in other ways, further limiting the ability to draw correct inferences from it [10, 43].

Researchers, designers, and stakeholders of college athletics should be concerned as tracking technology and data use surge ahead without addressing the challenges either in the design or the use. We are particularly concerned with how the current design and use upholds team power dynamics and further suppresses student-athlete agency. Clegg et al. [16] call for researchers to focus more on understanding athletes' experiences with tracking data than on the technology itself. Our work takes this perspective and focuses on the experiences that both athletes and staff want to have with tracking data—experiences that balance athletes needs for agency with the team needs for success and challenges current power dynamic.

2.2 Power Asymmetries and Sports Tracking Technologies

A particular challenge in the design, adoption, and use of sports tracking technologies is the way that they can reinforce or disrupt existing power dynamics within teams. This can be particularly challenging in US college athletic teams, where student-athletes face pressures to perform well individually, to contribute to their team's success, and succeed as a student—both for their education and to maintain eligibility to play—even as they also want to participate socially in college life [16, 17, 83].

One lens for understanding the role of tracking technologies has been boundary negotiating artifacts [45], especially when extended to consider wearables and other tracking technologies used in such team settings as extraction artifacts [43]. Drawing from boundary objects as articulated by Star [76], boundary negotiating artifacts have served as an important analytic within CSCW research to understand how material objects shape and push various inter-organizational dynamics important for collaboration.

One concern in boundary negotiating artifacts is the way that the artifact—or the data contained within—is procured. Reflecting on the ways in which athlete data are collected, Kolovson et al. [43] suggest that "extraction" is a more precise characterization of how teams procured data—through devices with capabilities and uses that may be unclear to athletes. To reflect this nature of data collection and the power asymmetry around these artifacts, they propose a new kind of artifact

that extends borrowing artifacts: extraction artifacts. This work defines extraction artifacts as: "A type of borrowing artifact where the collaborator procuring the artifact is in a position of power. Working from their position of power in the collaboration, the extractor determines the way in which data are extracted from a person, often in ways that person has limited capacity to resist and for uses that may not be transparent to that person. For personal data about athletes, such extraction often transcends existing boundaries, reaching into other contexts and even one's body."

The use of tools that produce extraction artifacts, such as wearables that automatically report athlete data to team staff, can exacerbate the power asymmetries present on teams. Even when presented as optional, student athletes are strongly incentivized—or coerced—into participating, as participating in tracking can help athletes achieve better individual and team performance and reduce risk of injury, while not participating in tracking could cause them to be excluded from games or practices or unfavorably looked upon by coaches [17, 40, 70, 71]. The use of tracking devices to automatically extract data from athletes, across a variety of contexts, diminishes athlete agency and increases staff control over athletes [16, 17, 43]. Further, when these data are not shared with athletes, they may not even know what about them is being communicated to others.

Though we build on prior work on tracking and extraction among US student-athletes in this research, this is but one area in which personal tracking technologies become tools of extraction and surveillance even as they may deliver individual and collective benefits. Other examples of contexts where someone or a group of people in power are extracting data through methods of surveillance or monitoring are: organizations conducting employee productivity tracking [51, 53, 85], GPS tracking of truck drivers [4, 65], tracking of gig workers [69], and universities tracking students [35, 67].

3 METHODS

This study primarily draws from speculative design methodology [6, 22], however, we combine several related methodologies to form our approach. The larger umbrella methodology of this study is Research through Design (RtD) [86], which creates new knowledge through the design process and embeds this knowledge in the designed artifacts. In the following sections we detail the video design process, the resulting videos, and the resulting empirical knowledge (the methodological knowledge is outside the scope of this paper).

Specifically, we draw upon the field and showroom practices of RtD. Our field approach is participatory [54] as we involved student-athletes as co-designers and researchers in the design process. And we draw from the showroom practices of speculative design [6, 22], discursive design [77], and critical design [22]. Discursive design [77] shows us how to spark discussion and reflection around preferred futures for the design and use of sports tracking technologies. We also draw on critical design [22] to critique the current sports technologies that reinforce power dynamics and extractive data collection practice. And we look to the future with speculative design [6, 22] to generate ideas for how to design and use tracking technology in ways that balances the goals and needs of student-athletes, coaches, and the team and do not reinforce power dynamics and extractive data collection practices. We also chose to use video prototyping [66, 79] as a medium to tell a story and convey knowledge about preferred or not preferred futures.

3.1 Creating the Videos

We engaged in a six-month process to plan and film three videos depicting possible futures for the design and use of sports tracking tracking in college teams.

3.1.1 Video Design Team. The lead researchers recruited a multi-disciplinary team including four student-athletes, [1] four students pursuing Design degrees within the School of Art + Art History + Design, and three students pursuing degrees in Human Centered Design & Engineering, all at the University of Washington, to participate in a six-month (two-quarter) for-credit research group [81] that would design and produce three videos. The expertise of the group was complementary: The student-athletes brought their lived experience and the other students brought their research and design experience to the group. Only three of the students had significant video experience prior to participating, including one of the student-athletes. None of the students had prior experience with speculative or discursive design methods.

3.1.2 Video Design Process. The videos were designed through a 10-week process. We started by introducing the video design team to speculative design and understanding our goals for the videos. To understand the conversations the videos should create, we reviewed findings from previous research [43, 62] and discussed the relevant lived experiences of the student-athletes on the research team.

Next we produced around 200 sketches of potential speculative technologies and use cases. Using these ideas, we next went through two iterations of storyboards that combined a speculative technology with a use case. Then, we combined similar ideas and discussed what we thought was most important to portray in the videos.

From this discussion, we converged on the themes that we would move forward with and divided into three teams that would each produce a video. The teams each consisted of at least one student-athlete and a group of design students with complementary skills so that each team would have the resources needed for producing a video. Each team conducted further ideation around their more specific themes for their video before converging on a final plan for the speculative technology and the story that they would portray. Each team presented their concept for feedback from the other teams and three individuals outside the direct research team who could provide feedback based on their expertise in speculative design, video prototyping, college sports, and relevant HCI and CSCW research. Teams then made changes made to reflect feedback, for example, creating more ambiguity around whether or not scenarios in the videos were preferable to create more room for discussion.

3.1.3 Video Production Process. The videos were also produced over 10 weeks. The three teams established at the end of the video design process continued working together to produce speculative videos based on the concepts they proposed at the end of the design process.

Video production varied for each team and the COVID-19 pandemic limited options for shooting, but each followed the same overall process: Each team further developed their concepts through writing a script, planning how the speculative technology would appear on screen, and creating a shot list that would provide structure on how to shoot each shot that would make up the video. As each team finalized their script and shot list, they scheduled shoots, recruited actors, and gathered props and other equipment to prepare for shooting.

Teams shot their video over a two-week period with minimal equipment used to shoot all three videos. All three videos were shot with iPhones set up on tripods, except one video which had a few drone shots, and we used lapel microphones and shotgun microphones to capture audio. All the

[1]The research team included, and the videos depicted, sports that many readers may think of as individual sports (e.g., gymnastics, tennis) as well as team sports (e.g., basketball, soccer). Within the context of US college athletics teams, however, this distinction is not meaningful. Even in sports that readers may think of as individual, US college athletes compete for team championship titles and therefore have collective interests. Consequently, our findings may not transfer to settings in which these same sports are pursued and won individually.

equipment we used was pre-owned by one of the research team members or borrowed. Following shooting, teams edited the videos over two weeks with several iterations of editing for each video.

3.2 Sharing Videos and Learning from Reactions

For the RtD methodology, Zimmerman and Forlizzi suggest evaluation of the design(s) as part of the research process [86]. Our final designs match the outcomes of RtD showroom practices, however, the suggested evaluation for showroom artifacts is to put them on display with the aim that those who experience the artifact will question or reflect on what the designers intended. Plenty of speculative works have followed this method [6, 57]. We sought for our evaluation to produce further knowledge, so we followed an approach closer to the field practice where we put the artifacts into the field and accessed what came of it.

3.2.1 Interviews & Small Group Discussions. We used interviews and small group discussions with student-athletes, coaches, and designers to elicit reactions to the videos. The sessions were conducted by the first and second author and two additional research team members. Most sessions had a secondary interviewer to assist with note taking, asking follow up questions, and managing the session. Each participant was compensated with a $30 Tango gift card.

During the sessions, each participant watched and discussed two videos. Following introductory statements and obtaining consent to record (5-10 minutes), the format consisted of watching one of the videos for approximately 5 minutes and discussing for 15 minutes, and then repeating the process for another video. One-on-one interview sessions lasted 60 minutes, except A1 whose session was 90 minutes as she asked to watch the third video. Small group discussions lasted 75 minutes to account for the extra time needed for participants to record their individual reactions before discussing as a group, to avoid the first person to speak having too much influence on the conversation.

The videos for each session were chosen at random or to ensure that all three videos were watched a similar number of times. *EnVisible* and *Informonocle* were viewed by 10 of the 15 participants. *Clippits* was viewed by 8 of the 15 participants.

For the discussion portions of each session, we encouraged participants to treat the video like a prompt. After asking for initial reactions to the videos, we asked a series of questions aimed at encouraging the participant to elaborate on their reaction to the video (See Appendix A.2 for a full list, e.g., "Was there anything that surprised you?") and what those reactions meant for what they wanted or did not want from the design and use of tracking technologies. We had prepared a set of questions for drawing out specific reactions to each video. However, the combination of videos and less specific probes (e.g., asking participants for elaboration of a reaction) were sufficient to support our research goal of generating discussion around preferred futures. Consequently, we did not use these questions in any interview: though they would have probed for specifics, we were also concerned about overly guiding participant reactions.

Data collection began in Fall 2021 and continued through February 2022. Each session was recorded on Zoom and afterwards the research team edited the Zoom transcript produced by Otter.ai to produce a cleaned transcript.

3.2.2 Participants. We had 15 total participants in the study: 4 student-athletes, 5 current or former athletics staff, and 6 designers (three of whom were former student-athletes). Half of the participants were recruited through a recruitment survey distributed online and the other half were recruited through connections of the research team.

We reached out to participants who responded to the recruitment survey to select for a diversity of sports and roles as we sought to have at least one group session per stakeholder type (student-athlete, staff, and designer). We also recruited participants through our extended networks to reach

Session	ID	Role in relation to the study	Age	Gender
Individual Interview	A1	Nordic skiing student-athlete	18-25	Woman
Group Interview	A2	Football student-athlete	18-25	Man
	A3	Esports student-athlete	18-25	Man
Individual Interview	A4	Track & Field student-athlete	18-25	Woman
Individual Interview	S1	Women's Basketball Coach	45-54	Woman
Group Interview	S2	Former university athletics staff	35-44	Man
	S3	Former university athletics staff	35-44	Man
Individual Interview	S4	Women's Rowing Coach	35-44	Man
Individual Interview	S5	Women's Volleyball Data Analyst	26-34	Man
Group Interview	D1	Designer for digital health platform and former student-athlete	26-34	Woman
	D2	Designer and former student-athlete	26-34	Woman
Individual Interview	D3	Designer for large fitness company and former student-athlete	26-34	Woman
Group Interview	D4	Former industrial designer, current human centered design student	26-34	Man
	D5	Former Samsung wearables designer	26-34	Woman
	D6	Former Samsung wearables designer	26-34	Man

Table 1. Information for participants in the video reaction sessions. The participant IDs refer to student-athletes (A), staff (S), and designers (D). Those listed in adjacent rows colored grey participated in the same session together.

roles that were not well-represented in the recruitment survey responses. In particular, coaches and staff can be challenging to recruit because of their schedules. And given a strong influence on the student-athlete perspective in our study, there is an opportunity to highlight or focus exclusively on the coach and staff roles in future research.

3.2.3 Analysis. In planning this study, we found no examples of a systematic analysis of reactions to a showroom artifact [86]. After discussion with other experts in speculative design, we chose to conduct a thematic analysis using codes we created based on the knowledge embedded in the artifacts and our research question [9].

Our initial code book had codes for the themes embedded in the videos (e.g., "EnVisible: Privacy vs. Trust and Accountability") and codes based on our research question for preferred design and preferred use that included sub-codes for collection and sharing (e.g., "Preferred Design: Collection"). We used these to identify reactions that indicated a participant's preferred future for the design or use of sports tracking technology, and the first and second authors developed the initial codebook prior to starting data collection. However, we did not expect all the reactions, reflections, or discussions to be what was intended in the design of the videos and wanted to leave room for codes we had not anticipated. As the first and second author analyzed the first five sessions, we applied our initial codebook and added codes and refined our definitions through regular meetings and discussion.

After the first five sessions, three additional researchers were added to the team to help with the analysis. This group aligned on our understanding of the codes again through discussion. To ensure reliability coding, each transcript was coded by two members of the research team, with the first author reviewing all coding. Coders continued to meet regularly and disagreements were resolved through discussion—coders reviewed the disagreement with the definition of the code and other segments with that code to decide the appropriate code or if a new code or sub-code was needed.

Due to the iterative and collaborative nature of our coding process and our goal of developing a shared understanding and interpretation of the data, drawing in the different perspectives of the research, we did not examine intercoder reliability.

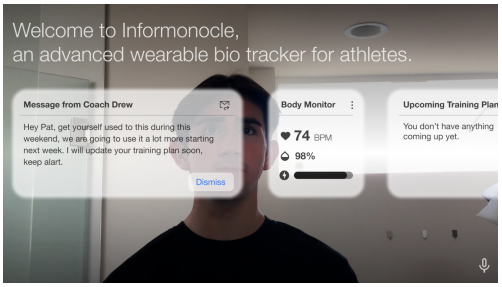
After collecting data from the first 10 participants, we began grouping data with the same code and building an affinity diagram within that code. Though some codes did indicate specific videos, we did not analyze the reactions separately by video. Following this initial analysis, we started to look across codes to develop themes describing preferred futures. We continued to add to the affinity diagrams and refine themes as we collected data from the remaining five participants.

4 FINDINGS

In this section we describe the videos produced by the research team and then what we learned from the reactions to the videos. Links to watch the videos are in Appendix A.1.

4.1 The speculative videos

Our video creation process resulted in three videos: *EnVisible*, *Informonocle*, and *Clippits*. The name of each video is also the name of the speculative technology represented in that video. As Research through Design and discursive design artifacts, the videos embed student-athlete and designers' perspectives on preferred futures and not-preferred futures for the design and use of tracking technologies. We outline these futures alongside a summary of each video.



(a) An image from Informonocle showing the AR display an athlete would see with messages, their data, and upcoming training sessions.

(b) An image from EnVisible where the main character answers a question from EnVisible, "Would you like to share your sleep data with coach Lydia?"

Fig. 1. Images from Informonocole (a) and EnVisible (b)

4.1.1 EnVisible: Surfacing Accountability and Trust in Sharing Data. The first video, *EnVisible*, presents a team performance tracking system that helps athletes and coaches monitor performance and recovery. Athletes are equipped with a data visualizer and voice operated system that helps them see their own data and compare it to their teammates. Through this system they are also able to control with whom their data are shared and what data streams will be shared automatically or not. Coaches have a similar set up for viewing any data the athletes choose to share. Both athletes and coaches also have one or more small round devices that are able to collect and transmit various types of data.

The *EnVisible* tracking system was designed with visibility in mind and different ways to make the idea of data visibility more tangible. For example, the visualizer is always on, keeping the

athlete's data and that of their their teammates visible. An indicator light represents whether the athlete's data are visible to others.[2]

Preferred future embedded in EnVisible. Using the core feature of visibility, our goal for this video was to convey tensions between **privacy, trust, and accountability**. When the athlete in the video stays up late to study for a midterm—compromising her sleep—she fears repercussions, such as being benched if her coach knew how little she has slept. She keeps her data private to mitigate some of these repercussions, but this decision could cause her coach and teammates to not fully trust her. In the video, however, the coach, unaware of the athlete's lack of sleep, decides to name her as a starter for the game without the information that her performance *might* be compromised, thus potentially compromising the entire team's performance. In this way, the video depicts athletes' individual needs for privacy and to make their own decisions to prioritize different elements of their lives—athletics, academics, well being, and socializing—and the team values of trust and accountability.

We intended for the viewer to raise these questions about their preferred futures: **Should team success or individual autonomy be prioritized? Do athletes have a choice to share their data?**

In this video, the research team decided to highlight sleep data because these data illustrate the tension between privacy and agency versus sharing a data stream that is important to athletic performance. It is, however, just one of many data streams, including ones collected during an athletic performance (e.g., concussion data, continuous heart rate, location), that could be valuable for coaching and training but that athletes might prefer to keep private or need agency to choose not to share.

4.1.2 Informonocle: A Lens for Data-Driven Decisions. The second video depicts *Informonocle*, a contact lens that is worn in one eye. The wearer sees information—messages, information about their body, and information about their team's training plan or calendar—overlaid in their vision (Figure 1a). The wearer can interact with the *Informonocle* interface using gestures and voice commands. *Informonocle* also includes a contact lens or set of glasses for the coach or other staff members to wear to monitor athlete data.

The scenario portrayed in the video focuses on a college track and field team and, specifically, on two athletes, Pat and Alex, and their coach. When the scenario starts, the coach feels his team has untapped potential and believes the *Informonocle* is the answer for improving his team and helping him make more data-driven decisions.

Pat thinks Informonocle will show his coach how hard he has been working, while his teammates are worried about when they will study if they can no longer choose to skip the independent additional training sessions. After Alex, the star runner is injured, both Pat and Alex blame the new data-driven approach supported by the Informonocle. Pat hacks the device to send fake data to his coach. Pat uses the hack when he wants to get some rest, which helps him regain control over his mental and physical wellbeing.

The scenario concludes by showing the outcomes for the three main characters. Pat lets his team know about the hack. The coach is strained looking through the data to decide who will replace Alex. In the final scene, the coach announces that Pat will replace Alex on the relay team.

Preferred future embedded in Informonocle. The team created this video with the goal of inviting the audience to consider how data-driven approaches may lead to resistance from athletes due to limits on their **agency** to make their own decisions, exhaustion on behalf of those who have to review the data, and difficult situations to navigate. While Pat initially hoped Informonocle

[2]We were not able to incorporate the green indicator light into the video. Though the prop lights up, this was not visible on camera and we lacked the video editing skills to add the light as a visual effect.

would make his training efforts more visible to his coach, it instead limited his ability to decide to rest or study instead of doing his independent additional training sessions (depicted as afternoon runs).[3]

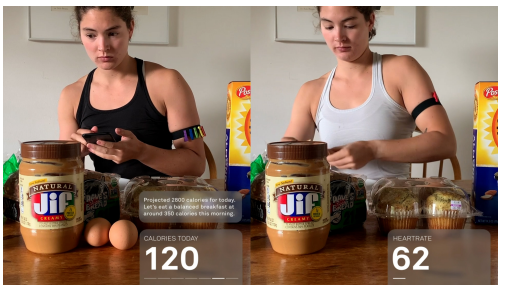
The research team intended to show how this extractive data collection could drive a student-athlete to **cheat the system** or use strategies of **obfuscation** such as lying or somehow producing fake data to manage how their coach views them. Pat sought to reclaim his agency by hacking the device to produce fake data. Though this goes against Pat's **integrity**, as he would never cheat in a competition or with performance enhancing drugs, it works. However, his use of the hack casts a shadow over his selection to replace Alex, in the eyes of his team and himself, which could also lead to doubts going forward.

Finally, though the video centers potential harms and resistance from the student athletes' perspectives, the team also wanted to emphasize the costs to the coach of constantly reviewing large amounts of invasive data, to the point that it also weighs on the coach's **mental health**.

4.1.3 Clippits: Using Data to Drive Personalized Training. In the third video, athletes and their coaches use *Clippits* to collect athlete biodata (e.g., heart rate, calories, GPS, steps, sleep). Each clip tracks one type of data, so the user can choose which data they want to track at a specific time. Clips can be attached to clothing or a provided elastic band and in the video are represented by small clothes pins. *Clippits* can provide personalized insight that can be used to adjust an athlete's training and diet based on their body.

The *Clippits* video shows two similar scenarios of a rowing student-athlete as she goes about her day. The two scenarios are shown using a split screen: the left half shows an athlete with many *Clippits* while the right side shows an athlete with only one *Clippits*. The same actor portrays both athletes to convey the idea that the only factor that differs is the amount of data collected. As the scenario progresses, the differences in the types of data collected lead to different effects on the athlete's day: when they wake up, at morning practice, at breakfast, during class, at afternoon practice, and at bedtime.

(a) Clippits were represented by small clothes pins. One athlete had 7, while the other athlete had only one (heart rate).



(b) An image from *Clippits* showing the split screen view. The student-athlete on the left is the one with more *Clippits*.

Fig. 2. Images from *Clippits*.

Preferred future embedded in Clippits. The team behind this video wanted to highlight tensions between **team and individual goals**. They hoped the viewer would see how **using data to drive personalized training** might affect an individual and the team. For example, in the

[3]In the NCAA, coaches can only be present for up to 20 hours of practice time per week. In endurance sports like rowing and running, coaches might assign secondary workouts for the team to complete on their own without coach supervision.

morning practice scene, *Clippits* data support greater personalization of the workout for the athlete wearing more *Clippits*, who is given an adjusted workout to prevent overtraining. In contrast, the athlete and her teammate, each with just one *Clippits*, receive the same workout, which prioritizes teamwork and shared experiences over individual performance.

Following this scene, all interactions with the *Clippits* data shown in the scenario with the athlete who had more *Clippits* (more data) were intended to show how using data can be a **tool for learning** and how the resulting knowledge can be powerful in tuning their daily routine to achieve greater performance.

Lastly, we sought to show the possibility for **technology inequity** where some teams or individuals might have more access to technology than others. The video depicted the athlete with more *Clippits* having several advantages as they trained and went about their day. This is analogous to how some teams have more resources than others, as well as how some individuals have greater resources they can spend on tools that support their training.

Though the *Clippits* and knowledge they produce are initially depicted as advantageous, as the day goes on, the team hoped it would be clear to viewers that these data also have an attentional cost and create more demands on the student athlete, raising the question: **How much is too much (data)?** The team of students working on this video had also considered having the athlete with more *Clippits* appear weighed down on one side by the *Clippits* to further convey the physical and emotional "weight" of collecting so much data, but decided that the visual metaphor of taking off seven *Clippits* effectively communicated the weight of the data.

4.2 Reactions to videos

The futures participants preferred, analyzed from the reactions to the videos, describe the need for defining boundaries on tracking and sharing, changing how tracking data represent athletes, and how they hoped data practices would shape or be shaped by team culture.

4.2.1 "My life is my life": Boundaries on tracking and sharing. All participants agreed with the need for some boundaries around what is tracked and shared and when that tracking occurs.

What to track. Clippits, and the discrete nature of the trackers for different data types, prompted reflection on how the types of data that are tracked could be tailored to each athlete's goals:

> *I would be totally open to doing a pick and choose of like the options I want [to track]. I think it could be helpful to have…I'm trying to think of which of the options I would use...I think sleeping might be helpful for recovery. Maybe nutrition tracking, like macros, would be helpful.* (A4 in reaction to Clippits)

> *Maybe they can choose what kind of data they want.* (D5 in reaction to Clippits)

Though there was some agreement that calorie tracking could be harmful and that heart rate tracking could be helpful, participants described a need to be able to tailor tracking to each athlete's goals and training plan. In the above quote, A4 said she might choose sleep and macros (protein, carbs, and fat), she also shared that it would cause her stress if she did not meet her goals for sleep or nutrition. This emphasizes that customization is not just about goals and training plans, but about how much data and what kinds are beneficial to an athlete. S1 commented that some of her athletes thrive with more information and some do not, regardless of whether data are positive or negative.

When to track. There was widespread agreement among participants, after viewing the videos, that tracking should be limited to training, or within the 20 hours per week allowed by the NCAA for training and competition. Student-athletes saw the utility of tracking data from outside of training, but they shared a need for privacy and autonomy in these other parts of their lives (A2,

A3). Coaches understood tracking beyond training as either violating student athletes' needs for autonomy (S4) or as breaking NCAA rules intended to protect that autonomy (S5).

A3 described how his preferred future included being given a tracking device at a training session and then having to give it back at the end of the session. He is comfortable with this because it is the coach's job, not the athlete's to set the training plan, so he should be following any directions from his coach. While A3 is okay with tracking having a strong influence during training, he would be uncomfortable with tracking anything outside of training:

> *I never have an issue if it's practice time because practice time is practice time... You can do whatever you want, tell me whatever you want in training time—I'll do it. But in this video [the student-athletes] hold on to [the tracking device]...Maybe it's something you give at practice and then take back after practice...But when you start having to get into everything that I do outside of the game, then it gets a bit uncomfortable for me.* (A3 in reaction to Informonocle)

While A2 largely shared A3's view, A2 was more unsure of the right way to balance privacy outside of training and the game with the value the data might provide to the coach, the team, or even the individual. In particular, A2 felt that quantification of outside behaviors might not account for individual variation in needs, and thus lead to problematic decisions:

> *It's not uncomfortable to have a coach monitor my sleep because it is something that's super important to recovery. But it also is that fine line and slippery slope of, 'Hey, my life is my life.' I know I can operate off of seven hours of sleep and maybe one of my teammates needs nine hours of sleep. So it's kind of that weird balancing act that I think is a tough thing to decipher.* (A2 in reaction to EnVisible)

A2 was concerned that a need to meet certain sleep numbers, or other metrics, could cause him to optimize for those measures even if they were not the right targets for him. A2 was particularly concerned about this for data collected outside of practice, where coaches may not have other data sources (e.g., seeing how an athlete performs in practice) to counter judgements they make based solely on the data. Further, when training, the sport is athletes' top priority, but for sleep or other activities outside of training, they are often balancing several competing priorities, such as academics and their social lives, with their goals as an athlete.

S4 and S5 also agreed that tracking should not happen during athletes' off time because it would violate NCAA rules and violate their privacy. S5 described the ways tracking could lead to a training overreach, calling wearables an "*encore training tracking device*": "*I almost stopped watching like 30 seconds in...I don't know endurance sports as well, but it'd be like a huge no-no for us to use an encore training tracking device for their optional practice*" (S5 in reaction to Informonocle). He cited the NCAA rule that limits the number of hours a week that student-athletes can be required to take part in athletic activities to 20 hours. Within those 20 hours "*it's expected that the athletes are just doing what they're told to do*" (S5 in reaction to EnVisible), but, because tracking could extend that reach into other times of a student athlete's week, tracking beyond those 20 hours would be "*totally not okay*."

Regardless of the NCAA rules, S4 described how tracking outside of training would run counter to his values: "*I personally just don't agree with tracking anything outside of the workouts, like, I don't know, I'm big on personal privacy. And I just don't agree with it...I think that it's an invasion of personal space*" (S4 in reaction to EnVisible).

D1 and S4 also noted how student-athletes need time away from the coach and team, and that extending the coach's view into other aspects of life through tracking could lead to them being always "on" in unhealthy ways. D1 emphasized that athletes need time where they are not "available", where they are able to get some separation from their sport. But with designs and

uses like Informonocole,they may feel they are constantly under a microscope and "*always being connected to the coach*":

> *So even though you're getting rest, you know in the back of your mind you're being tracked. Like a night's rest or when you're just wanting to chill on the couch and decompress, you always have that 'What am I not doing' or 'I'm not doing something, I'm not living up to my potential.' Like sometimes you need rest and rest is actually more beneficial. So it's that feeling of always being available actually can make you more tired.* (D1 in reaction to Informonocle)

Both athlete and coach participants critiqued the design and use of both the Informonocle and EnVisible for adding a constant presence that gets in the way of getting that space.

Discretionary tracking is not actually discretionary. The team who created EnVisible wanted to depict the option to share, even while noting that the power dynamics in teams would likely pressure athletes into sharing. Participants expressed the same in reaction to videos. S3 said the power dynamic removes the '*'whole notion of agency that players have to provide data or withhold it*," and D2 described experiences in which they were presented with choices, as a student athlete, that they did not experience as choices: "*'Oh well, we're not going to penalize you but we're going to favor everybody who does it.' So I've experienced that a lot as a student athlete where it's optional but it's not optional*" (D2 in reaction to EnVisible).

They also anticipated feeling unable to use any features that gave them the ability to temporarily opt out of tracking, as the missing data would also be a signal:

> *If you're sharing data and then you turn it off it's like very obvious that you, didn't want to share it, and so it would just I think it will lead the coach to like make assumptions based on like why you didn't want to share the data or like lead you to feel guilty or lesser than your other teammates if they're all sharing it and like throwing up beautiful sleep scores and you're just like I've had a really hard week and I just can't go to bed at night. But, in a perfect world, if everyone is just able to get 9 hours of sleep every night, I think having the option to share with the coach could be could be awesome.* (A1 in reaction to EnVisible)

Participants anticipated gaps in data leading, at best, to a conversation—"*Cough up the truth, you're not sharing the data so what's actually happening?*" (D1 in reaction to EnVisible) or "*Why aren't you sharing [your data]?*" (A2 in reaction to EnVisible)—while, more likely than not, it would just "*raise a red flag*" (A2). Team staff also anticipated that withheld data would prompt them to have a conversation, as otherwise they risked making bad judgements based on the incomplete data.

Boundaries on attention. Participants were not only concerned about the risks of always tracking, they were concerned about the risk of having the data always available for review or introspection. They said could demand too much attention from both coaches and athletes. S4 described this as "dangerous":

> *I think the constant presence like this space where someone goes away from practice away from your dorm room, your bedroom, or whatever is a space you can go to and like, yes, you can access that data. But I don't like that it is constantly present when that future technology is like on the charger. It's constantly projected on the wall, you know, aside from when she's asleep? So, I think that I really don't like that. I think that's dangerous. I think that's unnecessary.* (S4 in reaction to EnVisible)

D4 and D5 who both had experience designing wearable technology for major vendors described a dilemma around a design's demand on attention. D5 described that the more they added to

a design, the more it "*took [the users] time and attention.*" This caused a moral dilemma for D5 in designing wearable products and D4 found this was echoed in the video as causing a further dilemma for the users—coaches and athletes:

> *Personally for me, it was a kind of dilemma to design something that is informative and useful. But at the same time, it is harmful for their daily life, because we need to make them use the device or the mobile phone frequently.* (D5 in reaction to Clippits)

> *I thought that the constant feedback that the one on the left side, where there were many sensors, was giving was in a way, giving more data to the user and the coach, but was also making the use of the athlete more conscious about their daily practices and their daily routine, and when they don't need to be, that was encroaching upon their other parts of their life.* (D4 in reaction to Clippits)

With whom to share. The videos depicted sharing of athlete data with coaches and other team staff with whom student athletes already work. Consequently, most study participants reacted to this form of sharing and made suggestions about boundaries for sharing within that relationship. Some participant, though, suggested sharing with others:

> *I think it could be helpful for information to be shared with the specialist in that field. I would feel more comfortable having a nutritionist view the calories I'm eating because they're gonna view it through a lens of, okay, how can we help her stay healthy?* (A4 in reaction to Clippits)

Here, A4 notes that other expertise may be needed to interpret the data and may also support the full range of a student-athlete's goals. A4 continued that coaches may bring too narrow of a perspective to interpreting and acting on the data, leading to harm to student-athletes:

> *… versus [how] a coach might view those numbers, if they're particularly obsessed with the number of calories. [The coach] could be making you feel bad for eating something versus a nutritionist might be like, "okay, it happens."*

A4 also anticipated potentially getting better support by sharing with a therapist, who they anticipated being supportive rather than evaluative:

> *Or a therapist, if… you weren't able to run very much, if you weren't feeling well for the week, then they'd be like, "What's going on? Are you okay?" Versus a coach might see that as, "okay, they're just weak, they're not doing well" … because I feel like the coaches, as I've said before many times, can have a lot of power over the athletes and make them feel kind of isolated in some ways.* (A4 in reaction to Clippits)

Despite believing that sharing and reviewing data with other experts would lead to more supportive experiences, A4 expected that coaches would still want to see any data that exists. Even if coaches were to view the data, A4 hoped that engaging with other experts around the data could balance out more negative experiences that might come from sharing with coaches.

S5, viewing EnVisible, also noted that it was important for roles other than the coach to have access to the data. This model might include different "*intermediaries*" who review data and summarize them for team staff. Some roles might also have more "*data rights*" than others, such as athletic trainers "*should probably have the most access*" as they work to support individual athlete performance, safety, and wellbeing.

Like A4, S5 expected that coaches would want to see collected data, but wondered about whether coaches could have access to "*a less specific view.*" They believed this could prevent the data from overly influencing their decisions about how they interact with specific athletes, or whether they chose to play them:

> *If you need to protect individuals by anonymizing [the data] to a degree, where it's still useful, I think coaches are going to make that sacrifice because at the end of the day this becomes very un-useful if the trust between the student-athletes and the coach is broken, right?* (S5 in reaction to EnVisible)

This might work similarly to the features of consumer physical activity sharing apps, revealing an individual's progress toward a defined goal, or the direction of a trend, without sharing the specifics of the goal. As with features that nominally support athlete choice in when to track and when to share, participants expressed skepticism that features giving athletes a choice of which team members to share would present a true choice. S3 specially wanted top-down regulation on what data are tracked and shared. He felt that "*given the power dynamic between player and coach*," there is a "*need for really drawing a line in the sand in terms of what ethically data the team should or should not have access to*," and, "*it could be forbidden to have discussions around opting in or participating in [tracking].*"

Though the videos did not depict situations where data are shared between teammates, participants reflected on whether this would be valuable. D1 and D2 advocated against sharing with teammates because there is already competition for spots on the team and "*you don't need to add more to it*" (D2 in reaction to EnVisible). D1 emphasized tracking for "*more motivation to get better against yourself, rather than put you against your teammates*" (D1 in reaction to EnVisible).

Athletes, however described ways that sharing with specific teammates or the entire team could be beneficial. A1 has a teammate who uses the same device and is able to share data, and enjoys sharing with her teammate so long as it is for fun. A2 thought sharing could support better collaborating with teammates, similar to how watching game film together gives him the opportunity to work on strategy with his teammates. A3 thought that sharing data could hold teammates accountable who are not putting in the same level of work as himself.

4.2.2 How tracking data represent student athletes. Participants were unsatisfied with the way we represented student-athletes with data in our videos and had clear preferences for how to change this representation in the future.

A preference for trends over single data points. Our videos centered the short-term effects of behaviors, such as how not getting enough sleep could affect performance or readiness to train. This was inspired by the kinds of questions athletes and team staff in previous work wanted to use data to answer [16, 43] as well as our student-athlete researchers' personal experiences. The student-athletes involved in the video design also wanted to illustrate the anxiety, or fear, they would feel if they needed to stay up late to study but knew their coach would see their sleep data. This anxiety, also expressed by the student-athletes in the study, comes from concern that coaches will make too strong of an interference from single data points, such as benching an athlete for not sleeping enough because they believe the athlete will not perform well due to lack of sleep.

However, the athlete's fear of how short-term data are used highlights a disconnect between how athletes think coaches and staff view their data and how coaches and staff described valuing trends over short term data. Coaches and staff made it clear that they were concerned about using short-term data, noting that they understand the limits of short term measures. They said they would need a large amount of data, backed by a compelling statistical analysis, before they would make a decision based on data from wearables:

> *You could have an amazing game on like three hours of sleep and you could have an awful game on 10 hours of sleep...The [scenario in the video] almost seems like blame assignment. And I think coaches are meaning well with this but it is not statistically strong...Unless you start building up a season-long, however-long block you need to validate the data like,*

> *"Hey, your sleep actually correlates significantly with your performance."* (S5 in reaction to EnVisible)

Consequently, the coaches in our study preferred trends for showing progress and also for looking for consistent problems that might require interventions. S4 noted: "*If you start to see trends, where it's months, four weeks that are bad recovery, bad sleep, that makes me alert to look for… is there something wrong? Is there any illness, injury, whatever, to keep my eyes out for as a coach. And again, I don't know that I want access to all of that.*" S4 also perceived focusing on trends as helping them identify substantiated problems on which to follow up, rather than bouncing from one potential, and maybe unsubstantiated, concern to another. S1 expressed the same: "*Now if it was repetitive, like this kid for weeks and weeks and months isn't sleeping, isn't eating, then we have something to address*" (S1 in reaction to Clippits). She contrasted this with how "*the occasional cram for an exam, had to pull an all nighter, it's finals week*," would not concern her.

That said, athletes and team staff sometimes wanted to use long-term tracking data to understand potential short-term effects of their behaviors or choices. For example, S5 describes a "*better*" way of understanding how sleep affects performance, rather than measuring just the night before, collecting and analyzing sleep and performance data over several months or, ideally, longer and analyzing how sleep correlates with performance. This could support understanding potential short-term effects, such as Athlete X's performance improves significantly if they sleep 8 or more hours the night before. Or, Athlete X's performance is not significantly affected as long as they sleep at least 5 hours the night before. Such information is useful to both athletes and coaches for reaching peak performance, or not attributing a bad performance to the the wrong cause.

Though the coaches and staff were clear that they valued trends and that they would need a long history of data to understand the effects of a single day, they worried that short-term data could cause athletes to make the wrong inferences about themselves. S1 and S4 were concerned that athletes might "*fixate on one bad day*" (S4) and both expressed that they would not want their athletes to see their own data every day. S4 was also attuned to athlete anxiety about a single bad night of sleep being too consequential in a coach's decision to play an athlete. He called this "*terrible*" as he did not like to think of an athlete fixating on the short-term data when he is concerned about trends or consistent behaviors: "*do you sleep well over the course of a month, do you hydrate well over the course of the week, not just one day, like that sort of thing is more important to me*" (S4 in reaction to EnVisible).

Designers expressed similar concerns. D4, for example, expressed the concern that short-term data could lead athletes to shift their focus from the "*future to now*" (reaction to Informonocle). He strives for his designs to get the people who use the products to focus on progress because "*it's not really about the day-to-day goals, it's about the improvement over time and a history of improvement as well.*" Paralleling athlete concerns, he also was afraid that making short term data salient could imply to athletes that this is what coaches use to make their decisions, including penalizing athletes, when good coaches also strive to support the student athlete's holistic and long term success.

While many athletes expressed concerns that coaches and staff would make decision based on single data points, A1 described a more positive experience. Her coach does not react to the single data points that make her fell anxious, and instead helps her focus on important trends: "*I've never encountered a comment [on my training log] that's like wow why are you only getting five hours sleep. It's more like all right I'm seeing a trend of high resting heart rates, low sleep, and lots of intensity, let's see what we can do to get that resting heart rate down and prevent sickness from continuing to occur consistently*" (A1 in reaction to EnVisible). Seeing a potential problem or opportunity for improvement, or even success, backed by multiple data points also helps persuade the athletes that it is not a fluke and merits attention.

S1 brought up an additional concern about short-term data, specifically that it could suggest actions that a coach could not reasonably take. "*We're not going to cancel a game because it's finals week and my players didn't get enough sleep. That's just part of it, you know. It happens*" (S1 in reaction to Clippits). A challenge across participants' reactions is assessing whether a short term data point requires intervention, especially while the field is still learning the value and limitations of these measures. Neither athletes nor coaches wanted a single night of bad sleep to lead to benching an athlete, but they also (usually) did not want an athlete to compete when so fatigued that they risked injury. This raises the question: at what point is a single data point sufficiently certain—even if still uncertain—that team staff have a responsibility to act, out of either responsibility to an individual athlete or out of responsibility to the team?

Holistic representations of athletes, not single data types. Participants noted how the data in the videos failed to represent athletes holistically, and that they also had experienced this limitation of data provided by wearables and other tracking tools. "*Everyone involved is not just a data point, they're a human being with feelings*" (D3 in reaction to Clippits) and "*...the coach is looking at the athlete, not as human, but data*" (D4 in reaction to Informonocle). They noted the potential for too much of a focus on data to dehumanize athletes: "*I think it turns people into robots versus humans and athletes*" (A1 in reaction Clippits).

S5 commented on how data can also entice coaches to focus on controlling the behaviors that result in those data, when just checking in with their athletes might better serve the athletes and the team: "*The other part which might be even more valuable is the stuff that we can't control. The coaching staff always wants to control for better or for worse, they think for good, and my hope is for good. Right? But are [the athletes] eating well and sleeping well? Are they stressed out? I don't think there's a good replacement for just checking in with your athletes regularly. But sometimes technology can help with that*" (S5). Technology could support some check-ins, but it could not replace them.

D2 talks about how check-ins can facilitate supporting the athlete as a person, rather than focusing just on the dimensions in the data:

> *It's that they cared more about you and your numbers, even just in terms of your playing numbers, instead of you as a person. Like if you're not getting enough sleep: So what if you're only getting four hours of sleep? What's the reason for that? And they have to know the human to know the reasoning for that instead of just saying like 'oh it's going to negatively impact your performance'—make it better.* (D2 in reaction to EnVisible)

As D2 suggests, rather than looking at only getting four hours of sleep and how that could affect performance as the problem, step back and look at the situation holistically. Have a conversation. Maybe the student-athlete had to stay up and study for a test or maybe they are having trouble sleeping due to stress. Low sleep is a consequence of these problems, and approaches that mandate more sleep without engaging with the root causes will fail to support the athletes as people and are unlikely to advance individual or team goals. In contrast, identifying the human problems opens the door for supporting the student-athlete in managing the aspects of their life that are affecting their sleep.

The use of data to start a conversation aligns with hopes expressed in previous research that tracking data would prompt communication between athletes and coaches or help athletes and coaches substantiate and better understand concerns they raise [43, 62]. However, concerns expressed by participants in our study emphasize that the data could have the opposite effect—if athletes and coaches become accustomed to focusing only on what can be measured, communicating through the data and relying on it to make decisions, they may miss signs that a conversation is needed.

Risk of including only what is easy to measure. Concerns that tracking data are not holistic representations of athletes reflect another concern raised by participants: that adoption of wearables

and other automated tracking technologies can lead athletes and the team staff to focus solely on these measures in their coaching, rather than factors that may not be so readily sensed: "*[The video is] focused mainly on the physiological parameters, which is not all there is to, you know, progress in life, there are emotional and mental parameters also that are not recorded that inform your performance and progress overall which were not taken into consideration*" (D4 in reaction to Clippits). D4 continues by noting how the invasiveness of the sensors and primacy of the data they represent are likely detrimental to some of these emotional and mental factors: "*these were kind of being encroached upon by the scenario in which there were so many sensors.*"

In addition to concerns about reducing athletes to single data points or only including what is easy to measure, athletes and team staff in our study expressed concerns about how tracking and quantification can strip important context from their understanding of a situation. Watching Clippits, A1 commented, "*[the data] fails again to take into account discrepancies in the day that are just gonna like...stuff happens that isn't totally structured and planned.*"

For athletes and team staff, these aspects of context included not just other parts of life, but also how the team interacts with each other during play. This includes the "flow of the game" (A2) and "the opportunities a team sees together" (A3). D2 described how "*Sports aren't played on paper. There's so many more factors than just however many points someone scores or however many wins the team has*" (D2 in reaction to EnVisible).

Contextualization also supports a holistic approach because it could help coaches build empathy with athletes as humans and not as their data. For instance, D2 discusses a hypothetical scenario of how a "*really crappy 5k*" performance by a student-athlete may appear differently on its own versus when you take into account the "*30k the athlete has already run that week.*"

4.2.3 Data Practices and Team Culture. Athletes and staff all commented on how different data practices will be shaped by and in turn shape a team's culture. As noted above, athletes and staff expressed concern that reducing athletes to data that could be readily measured, a focus on short term data points, and decisions driven by narrow sets of tracking data could harm student athletes and the team and set the wrong culture for a team. Concerns like these led D3 to ask: "*Is there a way to build a sense of warmth or 'teamliness' or something that's not creating a toxic environment if you're going to have some sort of data or performance-based product?*"

D3's question was prompted by Clippits. She gave two examples from her experience where a specific approach was used to bring the team together and it was successful when the team embraced the approach together. In one case, the team embraced an approach developed at the University of Michigan called The Wolverine Plan [12], where individual peak performance data was used to structure goals for performance in everyday individual training sessions. D3's sport was rowing, so they used a peak performance pace to determine goals for endurance pace and anaerobic work. In the second case, she described how a teammate had knowledge of a "*low alkaline diet or whatever it was*" and her and her teammates were willing to try it if it would help them perform better. D3 said that this resulted in them performing well, but "*it was less the fact that we were all accurately doing whatever diet we needed to do, and more so on the fact that we all believed that it was going to work.*"

Participants saw two key ingredients for creating a positive culture around data use: (1) clear communication about intended uses, perhaps with shared decision making, and (2) engaging with the data in ways that promote wellbeing.

Clear communication about intended uses, including shared decision making. Participants noted a need for clear and open communication about the use of tracking data (A1, A2, D1). A3 suggested an initial conversation—when new technologies are adopted or at the start of

training—with everyone involved to set expectations for what data will be tracked and how it will be used:

> *Maybe if it's with the entire coaching staff and not just a single coach, plus any medical team involved, and even the sports psychologists involved, kind of a team effort and transparency to create a team-wide—"this is the kind of level we're looking at and this is the level that you need to be at".* (A3 in reaction to Informonocle)

After initial conversations, the coaches and team staff must continue to communicate about how they are using data. A1 and S5 expressed an additional preference for an educator or representative of the tracking technology company to work with the team to mediate use of the data, or if the design of the tool could also support learning.

A2 suggests that there also need to be individual conversations. In particular, they thought each student athlete could work with team staff to develop a plan for achieving their goals and supporting team goals, and then discuss whether and how tracking data fit into that plan. A1 agreed with the need for such conversations, and thought they could introduce and provide guidance on tracking technologies, but that they must emphasize (for athletes) that the tracking technology is a "*tool to manage yourself*" (A1).

Engaging with the data in ways that promote wellbeing. When A1 says a "*tool to manage yourself*", she is pointing at a tension that student-athletes face daily:

> *What do I prioritize? My personal wellbeing or the training that might be too much? Do I feel comfortable raising concerns that might be too much or do I wait for a coach to tell me you can not do as much as I initially required?* (S2 in reaction to Informonocle)

In Informonocle, Pat hacks his Informonocle so that he can prioritize rest when he needs it and make choices that are good for his physical and mental wellbeing. Though the hacking part of this scenario was not preferred by any of the participants, participants reflected on when a student-athlete should bring up their other needs or express concerns about an expectation versus when they try until a coach notices that it is not working and adjusts the plan—because if the athlete says nothing and the coach does not notice, the athlete may end up injured like Alex.

A2 and A3 both gave examples of a time when they reached a breaking point and needed to prioritize rest. A3 describes how he communicated this with his coach:

> *I know I've had this moment before where I'm so booked—practice is already pushing it, I can't do extra. And I've had times where I will just literally send the coach a message, through whatever messaging platform, and I'm just like "I just can't do this today, I need a break"* (A3 in reaction to Informonocle)

If athletes can be supported in learning how to use the data to manage themselves, they might feel empowered to prioritize, have that conversation with the coach or send that message. Coaches or other team staff might also support athletes in using data, combined with how they feel, to decide when they need a respite. Core to this is the idea that data can make training responsive to the individual athlete, rather than using the data to make the individual responsive to the coach.

Supporting athlete wellbeing and mental health also extends to how teams talk about the data. S2 said "*creating a positive atmosphere around [data] to begin with could ease concerns and the anxiousness that arises out of it.*" Similarly, A1 suggests adopting "*an aura of humor around [the data] that is going to create much healthier, happier athletes that are more adaptable to general life stressors and stressors around data collection.*" Participants thought this approach could be supported by the design of the tracking technology (S5), a representative from a tracking technology company who works with the team (S5), the coach (A1), or the athletic department (A1). They saw it as important that authoritative voices communicate a sense of not taking the data too seriously, which could

also help athletes feel more comfortable speaking up when they felt the data do not describe their current situation accurately or fully.

5 DISCUSSION

Previous research has made clear that athletes, and many coaches, do not prefer designs and uses of tracking data in sport that promote extraction. Such approaches upholds or even magnify coaches' power while reducing athlete agency and result in mistrust [16, 17, 43]. By taking a speculative design approach to designing three videos and analyzing reactions to these videos, we sought to identify preferred futures for the design and use of tracking technology and data. Participants in our study described preferred futures for boundaries around tracking data, how tracking data should represent student-athletes, and data practices to support a productive team culture.

In this section, we will discuss how to support athlete and team needs without extraction by framing decisions around creating appropriates flow of information, design requirements and use recommendations for balancing athlete and team needs. We also note other contexts where these recommendations, and our approach, may apply.

5.1 Addressing Extraction with *Appropriate Flow of Information*

To move toward a preferred future where tracking technologies are designed and used without coercion, extraction, or obfuscation, we argue that designers of tracking tools and those who plan for and oversee their adoption among teams should discuss and strive toward *appropriate flow of information.*

The term appropriate flow of information comes from Helen Nissenbaum's Contextual Integrity. Nissenbaum suggests **rejecting the idea that control over personal data is privacy and instead privacy should be thought of as contextual integrity, where privacy is dependent on the norms of the context that determine appropriate flow of information** [56]. This concept supports considering how information privacy and sharing needs may be individually or situationally dependent, e.g., with differences in what is appropriate during training versus competition or differences based on whether an athlete is injured or has specific goals. It also pushes designers and adopters to consider the checks and balances in place that might allow, for example, disaggregation or identification of individual data in specific situations (e.g., if the overall data indicate a potential health and safety risk).

As our participants and past research emphasize extraction or the explicit unrestrained sharing of athlete data with coaches and staff is the norm on sports teams. Athletes also have different expectations of for privacy because they understand that information is necessary for the coaches need to make decisions about the team and they can use the information to help them improve individually and as a team.

However, tracking technologies enable new streams of data collection that athletes may wish not to share because they are about their own body, they might give insight into their private lives, or athletes fear how the data will inform coaches' decisions.

Even though these new data streams may be relevant to team and individual goals, sharing them in the same ways as previous self report data can violate athlete expectations of appropriateness. Though athletes and team staff were, across interviews, aware that tracking data are different, they also noted that the social norms of monitoring have yet to be explicitly renegotiated socially, and worse, the designs of some current tracking technologies assume that the data should flow with the same ease as other types of data.

> *I think the technology itself is okay. I think that it basically being a wholesale, you can share everything or nothing. It was a little uncomfortable like that. That didn't feel*

> *right... I don't know that I agree with the technology to where it's like you can either share everything or nothing. I think that there's some amount where sharing is appropriate, and some where it's not* (S4 in reaction to EnVisible)

S4 preferred future in which tracking tools offer a granular approach to data sharing. However, putting that granular control in the hands of athletes would present a false choice—recall that discretionary sharing among teams is not actually discretionary—and so such controls are insufficient for achieving appropriate flow of information. Those involved in the design and use of tracking data must consider the social dynamics and incentives within teams. For example, a question that surfaces repeatedly and ties across the video themes and the reactions, is how to provide athletes with what they need—agency to make decisions such as staying up late to study for a test—while also providing the coaches what they need to support team performance–information about their athletes. A related question is if and when coaches or staff should look at individual athlete data?

Based on the experiences of the team—researchers, student athletes, and technology designers—who developed the videos and the reactions from the student athletes, team staff, and technology designers who viewed them, we articulate the following requirements and recommendations for design and use of team tracking technologies that support appropriate flows of information to balance athlete needs with the needs of the coach and the team.

We will also point out where future research could explore these requirements and recommendations further through the lens of contextual integrity. For example, how one recent study used principle of contextual integrity to access appropriateness of information flow and concern for employee surveillance in different scenarios [82]. Researchers could explore athlete, coach, and staff needs for appropriate flow for each type of information based on the sender and the recipient to define a transmission principle [7] for each data type. An additional challenge is that what is appropriate for one type of data, collected in a certain way, may not be appropriate for additional data types or even the same data collected in different ways (e.g., shifting sleep to automatic collection rather than self-reported may mean that how that information flows into team decision making may also need to change).

5.2 Design Requirements for Team Tracking Technologies

We propose design requirements for the team tracking technologies. Many of these requirements apply design patterns and capabilities familiar to CSCW and HCI more broadly, but are not the experiences of student athletes and team staff [17, 43, 52, 62] or, based on reviewing product websites, prevalent in the designs of current team tracking technologies.

5.2.1 Customization to team norms and roles. The design should provide flexibility for teams to decide which types of data are visible to different roles within the system, how and when each type of data is shared to different roles within the system, and how each type of data is represented to different roles within the system.

For example, athletes and coaches expressed a preference for a boundary of tracking only during training or having only data from training shared with coaches (A2, A3, S4, S5). The system could allow a team to decide that heart rate data from training times is always available to both coaches and athletes, but outside of training, only athletes can see their data.

The system could also support the team choosing to make the heart rate data be represented anonymously to coaches (see following section). And the same decisions would be available for other types of data and the team could make different decisions for those types. Other examples might include deciding not to collect sleep data, that sleep data is never shared with coaches, or that coaches only get an aggregated representation of sleep. If the design supports customization, a

team's use of tracking technology is not constrained by one design. A team can choose the pattern of data collection and sharing that works for their culture or approach.

Furthermore, customization could support differences in how people react to data. Athletes like A4 who like less data could turn off more data types or have data represented to them more abstractly or as a range. Athletes who love seeing more data could turn on everything that they wanted, but if they started to feel they needed a break they could use customization to get the break from the data.

To fully define all the customization needed, future research should consider seek to define a transmission principle [56] for each type of data and for each person it could be shared with. For example, if there is sleep data about one athlete, is the sharing of this data controlled and how is it shared with the coach versus another staff member? If one staff member has more specific data about an athlete than another, are there conditions under which they can share it?

The next section will build on the idea of customizing which data are shared and with whom to discuss different ways the data could be represented to different roles within a tracking technology systems.

5.2.2 Support Translucent Data Representations for Coaches and Staff. In social or group systems, designing for translucence can ease the tension between privacy and visibility of information [28]. Consider a translucent door to a room. This door would allow you to see if people are in the room and if they are close to the door but not the identity of those people or what they are doing. This supports visibility and awareness so that you do not open the door quickly and risk injuring someone on the other side, or it might prevent you from interrupting a meeting in progress on the errant belief that the room was empty.

Tracking systems could support the visibility of data to various team roles in ways that give them enough awareness of how student-athletes are doing (e.g., if they are recovered) to take necessary action, but represent the data in ways that do not reveal the identity of an athlete or specific data points that athletes wish to conceal. In this way, the coach is still able to monitor athletes to support their and the team's performance and wellbeing, but appropriate changes have been made to the flow of information to maintain athletes' need for agency. With designs for translucence, athletes could contribute data that support forming an overall impression of the team while having their concerns about individual consequences mitigated.

Translucence may better support trust and accountability than other approaches, such tools that allow athletes to modify or redact sensitive data. Previous investigations into such capabilities have found that the ability to edit tracking data could make both trackers and viewers uncomfortable and diminish their trust in the data and each other [24]. Translucence offers a compromise in design that preserves the big picture or critical information while modifying the details or way the information is represented.

Though there are many situations in which translucence could offer a good balance among competing goals, limiting the view into the data limits the ability to use that data to provide personalized coaching or safety monitoring. Consequently, for some types of data, they may be translucent to all members of the team staff, while other kinds of data may be translucent to coaches making decisions about plans for the team but more transparent to team staff providing guidance to the *individual*.

Through the lens of contextual integrity, translucence can be thought of as a transmission principle, with modifications made to the data as it is transmitted between different roles, such as anonymizing or aggregating the data, or specific conditions that must be met before disclosure takes place.

Ask when anonymous data could be sufficient. One way data could be represented to coaches or other staff is anonymously. Coaches or staff could still use data to make decisions based on trends or data from a majority of the team, but individual behavior would be protected. S5 described how coaches always want more data to put more aspects of the team's performance under their control, but felt anonymous data would be an acceptable compromise.

For example, if sleep data was shared anonymously, athletes could feel comfortable sharing without trying to distort their data, so coaches seeing the data could trust that it was accurate. This way of sharing could also hold athletes accountable to a goal of getting enough sleep, but athletes could still make a decision to put studying before sleep without the fear of anyone else seeing they specifically did sleep as much as agreed or planned.

However, in smaller teams and when coaches and team staff know their athletes well, supposedly anonymous data that is represented individually may be readily identifiable based on overall knowledge of athletes. This leads to our next recommended form of translucence, aggregation.

Consider representing only aggregate data. Data could be represented to coaches and team staff as a team average or as a box and whisker plot that shows mean, median, mode. To avoid identification of individual athletes, max and minima might not be shown or only the end point that is seen as "best" might be shown (e.g., the fastest time)–though this is complex, as for measures like sleep, too much and too little sleep can each indicate problems. Similar to the example for anonymous data, coaches would have information that they can use to inform their decisions for the team.

Another way to think about representing data as an aggregation is with a score that tries to account for several separate measures. For example, Whoop's or Oura Ring's recovery score combines heart rate variability (HRV) and resting heart rate (RHR) which can both give an indication of how recovered an athlete is or if they are getting sick (Kiviniemi et al., 2007; Mishra et al., 2020) and sleep quality. The algorithms used are proprietary, but it is possible that this score also accounts for trends in the individual measures that it combines. What the user sees is a score from 1% to 100% that indicates how recovered they are on that day. Whether or not measures like these are accurate is a separate discussion. However, if combined measures like recovery score can be validated, athletes might be more comfortable sharing these measures with coaches or others because they do not show sleep data on its own.

For some data, show only trends or emphasize trends over single data points. Reactions to the videos indicate that athletes, coaches and staff, and designers, valued trends in tracking data over single data points and also perceived trends as less threatening to their agency than a focus on individual data points. S4, in particular, stated that trends would be what he would want to see most. Representing data in a trend would be translucent and preferable. However, the trend would need to be a single number that represents a change over a specific number of days rather than a graph that might indicate a value on a specific day. For example, if the information needed to monitor athletes is a trend in the resting heart rate or a trend in their sleep, then a representation of one athlete's data might show that their resting heart rate is up by 10 beats per minute over the past week and their sleep is down by two hours over the past week. This information could be what is needed to know that an athlete is not recovered well or is getting sick. Furthermore, it might be much quicker to draw this conclusion from the trend than from the individual data points.

In current tracking data technologies like Whoop and Oura Ring, the design of the app where the user can view their data forefronts the summary of their data for the current day. For example, a recovery score or sleep score for today is the first thing the user sees rather than a trend. The apps do have graphs that show trends of heart rate and sleep over time but you have to scroll to look at these. Instead of putting single data points from the current day as the forefront, the designers of

these technologies could forefront the change over the past week or the past week versus the past few weeks.

Trend representations can also help address another problem inherent to the new frequency and range of contexts in which many types of personal informatics data are collected: the variability either prevents interpretation and action or leads to incorrect inferences and the wrong action [41]. For example, the adoption of home blood pressure monitoring should, in principle, lead to more frequent measures and thus better treatment decisions. However, for patients and clinicians unfamiliar with seeing this many measures (compared to, e.g., measures collected in the clinic), variability and lack of guidance in how to interpret it has instead increased treatment uncertainty [29].

The design of systems should also help the users understand what trends and variability are important. For example, for some measures, +5% or -5% might be typical variation, but +/-10% or more indicates something may need attention—but, people who are not familiar with such measures or seeing these measures collected with such frequency may not be prepared to assess what this variability means without support.

When identifiability is necessary, consider alert-based disclosure. There may be situations in which a coach or another member of the team staff needs to see identifiable data, such as when it indicates a potential safety concern. In these situations, the tracking system could prevent coaches, staff, or even an athlete from seeing their own data until a certain condition occurs. For example, coaches, staff, or other specialists could only see sleep or other data if the athlete's data indicates a potential safety or wellness issue, which would align with goals of preventing injury and promoting wellness. This would be similar to the goals of using passive tracking in mobile mental health interventions (Galambos et al., 2013; Saeb et al., 2015; Wang et al., 2016). Additionally, A1, A4, and S1 described how an athlete's own data can be a burden on themselves, alerts could lessen that burden by only letting athletes see their data under certain conditions. Alerts could be also applied and in combination with the previous three representations. For example, the alert could provide all the relevant data to the person who is alerted, only the trend to the person who is alerted, or it could provide nothing other than the alert.

Alerts have great potential for meeting the needs of athletes, coaches, staff, and other stakeholders, but alerts also present a risk of putting the decision making on the accuracy and validity of an algorithm.

5.2.3 Enforce Transparency for Student-Athletes. Though we argue for translucency for team staff, we argue for transparency into the data and uses for athletes. Visibility of data and access to data in a sports tracking system represents power and agency and yet, in many teams, athletes track and report data with no visibility into their own data or what team staff see [43].

When tracking technologies extract data from athletes for the coach's use while giving athletes limited or no access to their data, this reinforces a coach's power. Limiting athlete visibility into data can also leave them to imagine what representations of them team staff see, shaping their behavior and tracking in response to these imagined uses.

Such limits also impair athletes' ability to participate in informed conversations about how the data are used, what they might indicate, and ways in which the data may be flawed (that might, in turn, shape the use of the data). We argue that athletes cannot meaningfully consent to tracking if they do not have access to what the data show and how they are used [40]. This can additionally erode trust among teams.

Though we argue for transparency into the data for athletes, we caution that this does not mean always making the data highly salient to athletes. In previous research, athletes and team staff expressed concern that, when athletes focus too much on the data, it inhibits athletes from

listening to their bodies and that fluctuations in data leading up to competitions could make athletes unnecessarily anxious, preventing them from being present and performing in the moment [43, 62, 78]. In our study, A1 and A4 described how seeing their own data can cause anxiety and distress, and S1 and S4 both said they would not want their athletes to see their data all the time for the reasons A1 and A4 discussed. Previous work suggests features such as capabilities inspired by Screen Time to let athletes know when they are at risk of "getting lost in their data" [16].

5.2.4 Scaffold interpretation of tracking data. As with other settings in which personal informatics has been adopted, participants in our study and previous studies involving tracking data in sport [16, 33, 43, 84] expressed a need for support in interpreting tracking data. This included making the correct inferences while avoiding incorrect inferences, knowledge about the appropriate duration at which to examine trends for different kinds of data, and the value and limitations of different tracking technologies. Further, one of our other design recommendations–enforcing transparency for athletes–is only as athletes' ability to understand the data they are seeing.

Participants in our study noted that they need support not just for understanding the health or performance implications of a particular kind of data, but also data literacy and avoiding common confounds in interpreting data. For example, system designs should both avoid implying causality in the presentation of data when it does not support such a claim, and systems should also guide users to understand concepts such as correlation versus causation. Within our research team, we speculated about whether tools might even go further, such as in supporting athletes and trainers in developing n-of-1 experiments [39] in their training plans, but this was not specifically brought up by participants.

Ideally, this scaffolding would be built into the tracking and analysis tools themselves, providing both tutorials and in-the-moment, in-context support. However, while tracking within teams is relatively new, designers may not be able to anticipate the full range of support teams or individuals need or know how to design for it. Consequently, especially as teams are beginning to adopt tracking tools, vendors should consider embedding representatives with teams to support effective use of the tracking tools. This could be modeled on existing collaborations to validate wearable technologies to provide a resource for other researchers, leagues, teams, and individuals [64], though we emphasize that it must go beyond technical support and validation–what vendors most commonly support now–to also include interpretation of the data and limits of those interpretations. One hesitation we have with this recommendation, though, is that vendors have incentives to paint their technologies in a rosy light, and so independent expertise may also be necessary.

5.3 Recommendations for the Use of Student-Athlete Tracking Data

Even if device and tracking tool manufacturers meet the design requirements outlined above in their products, the ways that teams adopt and use (or do not use) the tools will continue to shape experiences. Consequently, we recommend practices for team use of tracking data that can help achieve the preferred futures described by athletes, team staff, and designers in our study.

5.3.1 Setting Expectations for Data Collection and Use as a Team. Several of the design and use recommendations we propose in this paper are intended to promote or preclude certain uses of tracking data, but even within these constraints, there remains a broad range of ways that teams might adopt and use data, including what data they collect and how, frequency of access, which roles have access, and circumstances that to someone on a team accessing identifiable data.

To support developing an appropriate flow of information for each team, team staff should, at a minimum, communicate plans for collecting and accessing data and show athletes examples of how team staff will view the data. Participants also wanted shared decision making around

these practices, such as having student athlete representatives involved in setting and periodically reviewing the team's approach and in defining consequences if individuals break team policies.

This communication and shared decision making can make information flows and uses visible. Not only does that contribute to an appropriate information flow, but it also can ameliorate student athletes' current fears about imagined uses of the data. For example, though team staff in our study expressed that they could not anticipate making a decision based on a single data point, such a one night of less sleep, students athletes in our study and previous work expressed concern about such decisions based on very short term data and even falsifying tracking data (e.g., giving a tracker to a roommate who was turning in early to inflate a sleep score) to avoid such potential decisions [43]. Clarifying uses (and non-uses) could reduce current misunderstandings and anxieties about the use of tracking data.

5.3.2 Engage Specialists with Relevant Expertise in Interpreting Data. Related to the previous recommendation of setting expectations for appropriate flow of information, A4 and S5 both described preferred futures where an appropriate flow of data is sharing specific sets of data with others according to their specialty: the combination of their expertise and their role. For example, previous work focuses on the role of the athletic trainer, who is responsible for athletes physical wellbeing including treating acute injuries, preventing and rehabilitating injuries, and collaborating with doctors [43]. Because their goals are to support individual athlete wellbeing, their motivations and needs differ from the coach and athletes may want to share or feel comfortable sharing more data with them, especially if the athletic trainer is able to help them prevent injury.

University athletic departments also employ other specialists, such as a physiologist to support athletes' mental health, with whom it could be appropriate to share a different set of data than the coach or athletic trainer.

Beyond athletes having the agency to decide with whom they will share the data, sports teams will also need to decide if certain roles should not be able to receive certain types of data. For example, a team could decide that a coach should not receive sleep data at all, and that sleep data should be the responsibility of another role or a specialist. This could alternatively be determined by policies (See Section 5.3.4).

5.3.3 Avoid Reliance on Easy-to-Track Measures—Integrate Self-Report and Context Data. The data-driven approach portrayed in Informonocle or moments in the other videos where data was given more value than the human experience prompted participants to discuss how tracking data represents athletes. Specifically, they were concerned that a focus on data can reduce athletes to what can be readily measured and they argued for a more holistic approach to the design and use of tracking technologies and data. This approach would use tracking data to augment and support, but never replace or take priority over, an athlete's lived experience and the expertise of the coach, staff, or other specialists.

Previous research describes the effective use of a wellness survey with athlete self-reported measures (ASRM) such as soreness and rate of perceived exertion with heart rate [43, 70–72]. These represent both objective and subjective information that can only (currently) be tracked through self-reporting, and these data could provide additional contextual insight about what is going on with an athlete's body. Evidence supports that ASRM can better support conversations and coaching than some objective measures collected by tracking technologies [72].

However, coaches and staff in a previous study believed that collecting data would allow them to make more data-driven decisions and even discounted their own expertise in favor of the data [43]. The preferred futures expressed by participants in our study indicate that athletes, coaches, and staff should not assume that data collected by technology is better—tracking data should be used to augment ASRM or conversations with athletes, not the other way around.

Additionally, participants in our study placed a high value on athlete-coach and athlete-staff conversations, which tracking data cannot replace. Coaches and staff should consider that the increased attention required to analyze data may draw their time and attention away from having these conversations. When deciding to adopt tracking technology, coaches and staff need to make sure they will be able to prioritize the humanizing check-in conversations that they value, that they are equipped to educate athletes about the data they are collecting, and that their process can involve adding context gained form conversations to their data analysis.

Windt et al. propose a framework for the adoption of technology in sport that prompts athletic organizations to ask questions such as whether the information is helpful, if the information can be trusted, if they can effectively integrate, manage, and analyze the data, and if they can implement it into practice [84]. Each of these categories includes a set of follow-up questions, many of which focus on data quality, resources for data cleaning, storage, and interpretation, burdens associated with collecting the data, and whether the organization's culture is open to adapting and using data.[4]

Many of these questions seemed directed at the risk of *under*-use of tracking data or the investment in the tools. Participants in our study, however, were equally if not more concerned about the risk of *over*-use of the data and it supplanting, rather than supplementing, self-report data and conversations that better communicate context. To address these risks, we recommend expanding the the framework to include questions such as: *Should the tracking data under consideration compliment existing data sources, such as ASRM, or should it replace it? How will the data support conversations? What safeguards will you have in place to ensure that data augment athlete and staff expertise rather than override it?*

5.3.4 Develop policies that ensure a standard of protections across the league or athletic organization. Participants noted how the NCAA, the relevant organization governing collegiate athletics in the US, has a role in developing policies that safeguard student athletes and that are intended to prevent teams or specific coaches from engaging in extractive or abusive practices to gain a competitive advantage.

For example, S5 felt that tracking outside of training would violate an existing NCAA rule that limits the number of hours a week that student-athletes can be required to take part in athletic activities to 20 hours. Similar policies might establish the boundaries that both student-athletes and coaches want to set for tracking and sharing data. Participants expressed a desire for policies to also extend to describe features (such as the design requirements outlined above) of technologies that may or may not be adopted and the ways in which they may be used.

Teams also can have access to very different resources and expertise and they also compete at different levels. In the NCAA, teams are categorized according to three divisions, which roughly correspond to resources and some policies differ. As a consequence, some policies might be appropriate for an entire organization, while other policies might need to be tailored to the division level. Other policies may need to be sport-specific.

To develop these policies, the NCAA could partner with researchers and practitioners to define transmission principles in policies that govern the use of sports tracking technologies. These might define which types of data can be shared, with whom, and how. For example, the NCAA or other organizations could determine that athlete sleep data should never be shared with coaches, but it can be shared with athletic trainers (staff responsible for athlete's health) as a trend so they monitor their athletes' well being.

[4]While not the focus of this section, we also argue *against* their recommendation to pursue invisible monitoring opportunities, as it violates principles of transparency and agency described elsewhere in this paper.

5.4 Urging caution in adopting tracking in organizational settings

Though our work is situated in the context of US college athletics, the tensions present in this context—power asymmetries that have the potential to lead to abuses, and seeking to balance reliance on the organizational hierarchy and expertise and preserving individual autonomy, individual goals and organizational goals, and short-term performance versus long term well-being and functioning—describe many other organizational settings that incorporating tracking as a tool.

Employee productivity and health tracking, like the adoption of tracking technologies in sport, is increasingly prevalent [37, 51, 53, 85]. GPS and other tools are used to track truck drivers and gig workers [4, 65, 69], often initially in the name of safety, but they also become tools for enforcing management's idea of how workers should spend their time and penalizing them if they do not. The power dynamic and extraction of data in the employee-employer relationship is similar to that of the athlete and coach. Employers extract productivity data from their employees, which reduces their agency to do things as simple as taking a bathroom break [37]. Like sports tracking technologies, these productivity trackers also fail to capture the human experience with a holistic approach of productivity.

Similarly, education systems engaged with various forms of tracking students and educators. Universities have installed technology that uses location or proximity data to track college student attendance [35] and course platforms, like Canvas, can provide instructors with tracking data about student engagement with their course content [67]. Educational settings also continue to flirt with wearable data as input for decisions like learning differentiation and ways to engage students [8, 11, 42] encouraging students to connect their out-of-school behaviors with learning outcomes [60], or facilitating social emotional-learning [60]. And, perhaps, unsurprisingly given the adoption in collegiate athletics teams, physical education instructors have also expressed interest in wearables [2].

CSCW and HCI research has also described adoption of tracking tools within families [18, 47, 50, 58, 59, 75]. Though obviously different than workplaces or schools, family members also face challenges navigating power, privacy, and the division of the labor associated with tracking even as they find value in using the data to support communication, coordination, and connection.

Before rushing to adopt tracking in these or other organizational settings, however, we encourage designers and potential adopters, as well as policymakers, to consider the perspectives of the athletes, team staff, and designers represented in this study. Some of our design and use recommendations may be readily adapted to these other settings, though it is also possible that other settings may benefit from repeating our method with representatives from that organization: engaging in speculative design of future scenarios (whether via video, storyboard, or another medium), and then soliciting reactions from others. Notably, in our study, even team staff, who often started with strong motivations to access to more data and more transparently, expressed the need for boundaries when they viewed the scenarios through athletes' perspectives.

6 CONCLUSION

Based on the design of three speculative videos and analysis of reactions to these videos from student athletes, team staff, and technology designers, we describe preferences for the future of tracking technologies in college sports. To support achieving these preferred futures, we propose:

- Design requirements for sports tracking technologies intended to be used in a team setting, including customization to team norms and rules, translucent data representations for team staff, transparency for athletes, and providing scaffolding for interpretation of tracking data.
- Recommendations for the use of student-athlete tracking data, including engaging specialists, setting expectations, using tracking data alongside information that better represents context

and always in communication with athletes, and developing NCAA policies that constrain what tracking tools teams can adopt and how they can use them.

These recommendations reflect what athletes, team staff, and designers generally saw providing balance between individual and team goals, and between sport and other aspects of life. These recommendations also create important safeguards against concerns raised by those who contributed to the speculative design process and participants who reacted to the videos. We note that existing frameworks for deciding about the adoption of tracking technologies in sport (e.g., [84]) are oriented around preventing under-use of data data, and we argue for extending these frameworks with questions that also prevent overuse and extraction and that support athletic organizations in developing appropriate information flows around the data.

Though our findings and recommendations were developed specifically in the context of US collegiate sports, this setting has similarities to many other contexts in which tracking tools are being adopted. Applications of our research approach and adaptations of our recommendations may also support better uses of tracking—those that support a range of goals while protecting individual agency and privacy—in those settings as well.

ACKNOWLEDGMENTS

We thank our participants for sharing their experience, opinions and perspectives openly. We also thank a number of folks who provided advice on this project including: Kate Starbird who provided feedback, critique, and support on this project, Tyler Fox who inspired the approach in this project and later provided advice on the methodology and critique on the videos, Audrey Desjardins who gave advice on the methodology and ways to teach the methodology to the research team, and Kristin Dew whose work inspired the structure for student-researcher involvement in this project and who provided advice on managing the research team. There were 14 student researchers involved in this project whose time and hard work made our contributions possible: the video team—Jenna Phillips, Claire Marion, Lark Skov, Brandon Wong, Ciana Yi, Dustin Mara, Nicki Chan, Chris Hong, Paul Fallon, Naomi Chau, and Drew Nevins—who dedicated themselves to a project that took place mostly virtually in 2021, and the video reactions team—Akshay Rawat, Nisha Jain, and Roz Gillie—who collected and analyzed video reaction data. This research was supported in part by the US National Science Foundation under award IIS-1553167. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Science Foundation.

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A APPENDIX

A.1 How to watch the speculative videos

The speculative videos described in this work can be watched on YouTube at the following links:

- EnVisible: https://youtu.be/uHzq3wFvWXA?si=mK2xGmtS86NeiSbO
- Informonocle: https://youtu.be/x_xYZEb4U84?si=a3ZbNRL35X9WGOyF
- Clippits: https://youtu.be/BjcG0EzUB8A?si=aTRONci9SpkYBowF

A.2 Interview and Group Discussion Questions

After asking for the participant's first reaction to the video and follow up questions based on that reaction, we used the following questions to further explore their preferences and attitudes:

(1) Was there anything that surprised you?
(2) Did anything make you uncomfortable?
(3) What did you like?
(4) What did you dislike?
(5) What does the video make you think about wearable/tracking technology?
(6) If we looked out 10 years from now and this was a reality...how would you feel about that?

We asked 1-4 most frequently, along with probing for elaboration on responses, while we did not ask questions 5 and 6 of all participants, especially if earlier responses had already addressed these topics.

Received July 2023; revised October 2023; accepted November 2023