Personal Data and Power Asymmetries in U.S. Collegiate Sports Teams

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Collaborations increasingly draw on personal data. We examine personal-data-supported collaborations in a high stakes, high-performance environment: collegiate sports. We conducted 22 interviews with people from four common roles within collegiate sports teams: athletes, sport coaches, athletic trainers, and strength and conditioning coaches. Using boundary negotiating artifacts as a lens for analysis, we describe an ecology of personal data in collaborations among these four roles. We use this ecology to highlight tensions and foreground issues of power asymmetry in these collaborations. To characterize these power asymmetries in the collaborative use of personal data, we propose an extension of boundary negotiating artifacts: extraction artifacts.

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, power, data-supported collaboration, boundary negotiating artifacts

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1 INTRODUCTION

Personal data have the potential to support collaborations in a myriad of contexts where people work together to accomplish shared goals. Self-report and sensed data can help patients work with health providers to diagnose and manage chronic conditions (e.g., [10, 11, 19, 20, 48, 49]), and these data can also help families coordinate around their health (e.g., [39]). These data-supported collaborations succeed when all parties are in agreement about the goals for the collaboration and how the data can support those goals and when all parties can contribute their expertise to interpreting and acting on the data [10, 11].

Athletes and sports teams have long used data to inform decisions, for example, to decide a starting line up for a basketball team or which runners should represent the team in a relay event. Teams record many types of data, such as lap times of runners and swimmers captured by stopwatches, multi-dimensional "stat" sheets for basketball and softball teams created by human

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recorders, and spoken or written athlete self-reports (e.g., sleep, nutrition, and general wellness data [47]).

Many of the same technological advances that facilitate greater use of personal data in patient-provider collaboration are also changing data practices for athletes and teams [41]. Many athletes now use wearable tracking devices. Teams can collect self-report data with higher frequency and can more easily aggregate individual and team data. Sports teams at all levels are incorporating these data into their collaborations and decision-making. As they do so, these data introduce new challenges for data collection, data representation, data-supported collaboration, and data privacy and surveillance. For example, devices that track everyday behavior (e.g., sleep) outside of practice and competition can support management of training and understanding the relationship between tracked behaviors and performance. However, such tracking can further extend the staff's reach into various aspects of an athlete's everyday life.

At the highest levels—U.S. collegiate teams, professional teams, and competitive club teams in Europe—sports teams function through complex collaborations across multiple team members who take on distinct roles in a high pressure environment that has time- and safety-critical elements. These roles include athletes, sport coaches, strength and conditioning coaches, athletic trainers and other medical providers, managers, and statisticians. Team members work together between and across roles towards a common purpose (i.e., winning), but at times also prioritize shared goals differently such that they are in tension with one another, necessitating coordination across roles.

In this paper, we focus on how sports teams collaborate around personal data from multiple sources—stats recorded by hand, athlete self-reports, medical assessments, and wearable tracking devices. We further focus on the National Collegiate Athletic Association (NCAA) in the United States, which includes 19,750 teams and 490,000 *student-athletes* across 24 sports [35]. The term *student-athlete* represents the NCAA's commitment to support student-athletes academically, athletically, and in their future careers, but it also hints at challenges NCAA athletes face: being a college student (e.g., courses, pursuing a degree, career exploration, and social events) and being a high performing athlete (e.g., training, traveling for competitions, competing, and staying healthy) [55].

The complex collaborations across multiple roles around several sources of personal data, combined with the tensions between roles and the introduction of new data collection technologies, creates a rich study context for Human-Computer Interaction (HCI) and Computer-Supported Cooperative Work (CSCW) researchers. We delve into this context through these research questions: *How are personal data currently used in collaborations in college sports teams? How do personal data support team and individual goals and what tensions arise?* We anticipate that results of this research could inform studies of other high-stakes collaborations based on personal data, particularly those in which individual and team goals are sometimes at odds.

To address these questions, we conducted 22 interviews that included athletes, coaches, athletic trainers, and strength and conditioning coaches from seven sports at three institutions in the United States. In our analysis, we use Lee's theory of boundary negotiating artifacts [23] as a lens, which provided organization to the otherwise non-routine collaborations in our data and a language for discussing the nuances of these collaborations. Previous work examining the use of personal data in collaborations noted challenges with—and the importance of—goal alignment between roles in collaboration [10, 11]. Our research further foregrounds issues related to differing goal priorities, including power asymmetries and privacy.

Through this research, we contribute:

(1) An ecology of collaborations, using personal data, across four distinct team roles that highlight goals for use of this data as well as sources of tension, such as power asymmetries, differing priorities, lack of access to or ability to interpret data, and reduction of student-athlete agency.
(2) Challenges for designers of systems that facilitate collaborations using personal data, such as the consideration of how the design of tools that collect data may reinforce or challenge power asymmetries.
(3) A new type of boundary negotiating artifact, *extraction artifacts*, that are created when data are taken directly from someone in one role by someone in another, who then creates an artifact that is used without any influence of the originator. These artifacts highlight power asymmetries in collaborations.

Together, these contributions can inform designers seeking to better support collaborations around personal data and boundary negotiating artifacts, specifically related to 1) differing goal priorities, and 2) issues of power asymmetry, surveillance, privacy and agency.

2 BACKGROUND AND RELATED WORK

Our research draws on theories of collaboration in CSCW, applications of these theories and other work that describes collaboration in group informatics, and work that demonstrates the potential of sports teams as a context for GROUP, CSCW, and HCI research.

2.1 Boundary Objects and Boundary Negotiating Artifacts

Star and Griesemer's boundary objects [50] and Lee's boundary negotiating artifacts [23] both highlight the role of material artifacts in coordinating disparate perspectives in collaboration. Boundary objects are conceptualized as artifacts that easily cross boundaries by translating information across different viewpoints in a group collaborating towards some shared goal (though individuals may also have their own goals).

Lee, however, pointed out that the concept of boundary objects depends on a standardized structure for collaboration and is too rigid to describe non-routine collaborations and account for artifacts changing across contexts or transforming into new artifacts [23]. In response to these limits of boundary objects, she proposed *boundary negotiating artifacts* [23], in which her main postulate is that boundary artifacts are used to negotiate and push boundaries rather than the effortless translation ascribed to boundary objects. Lee's boundary negotiating artifacts are more fluid in their roles and may change according to context and use, and so they better describe artifacts used in non-routine or novel collaborations. This is especially true where, as Lee suggests, artifacts are used in sets of practices that are not always wholly agreed upon by the participants involved, which highlights the role of these artifacts in negotiating existing or new practices.

Table 1 describes Lee's five types of boundary negotiating artifacts.

2.2 Boundary Negotiation and Personal Data

Previous research in CSCW and HCI shows the potential of using personal data to support collaborations intended to further individual health and well being [10, 11, 19, 20, 48]. In particular, Chung et al. draw on boundary objects and boundary negotiating artifacts to examine and support patient-provider collaboration using patient-collected health data [10, 11]. Patients and providers create boundary negotiating artifacts in preparation for and as part of their interactions, but various breakdowns in communication occur due to limitations of these artifacts and of practices around their use [10]. These collaborations work best when patients and providers agree on the goals for tracking and the roles for collecting and reviewing data, and when each are able to contribute their expertise [10, 11].

Self Explanation Artifact	Artifacts created by an individual for their own learning, organizing, recording, remembering, or reflecting. They can turn into another boundary-negotiating artifact when shared with others.
Inclusion Artifact	Artifacts created when self-explanation artifacts are shared with others and discussion around it reshapes it into a new idea and/or artifact. Inclusion artifacts facilitate discussion of new ideas.
Compilation Artifact	Artifacts created through the compilation and organization of information from different sources. These artifacts are used to pass crucial information, resolves conflict and bring the goals and understanding of two or more communities of practice into alignment.
Structuring Artifact	Artifacts created specifically to be used by other people to communicate a hierarchy, ordering, or direct or coordinate the activity of others. Whereas other artifacts can be more passive, these artifacts have an action component to them.
Borrowing Artifact	Artifacts taken from the original creator, augmented without the creator's input, and used in an unanticipated way. These artifacts are defined by the procurement of the artifact, not the creation, and, therefore, can be used as another type of artifact.

Table 1. Types of boundary negotiating artifacts [23].

While Lee noted the value of boundary negotiating artifacts in describing non-routine and novel collaborations, the use of boundary negotiating artifacts in describing patient-provider collaborations shows that the concept can also apply to more structured collaborations. In these collaborations, much of the value of boundary negotiating artifacts comes from their ability to account for what happens when the structured collaborations have to encounter the messiness of everyday life. In our context—in which teams have formal roles and routine activities—we find similar value in boundary negotiating artifacts to explain the movement and use of data between different contexts and roles.

Other CSCW research focuses on collective personal informatics practices such as when families or social support circles work together to support an individual managing a chronic condition [33, 39]. These studies emphasize the need to study dynamics between roles, collaborations around data, and how groups go about achieving a shared goal of supporting personal data tracking for an individual with a chronic condition.

Chung et al.'s studies focus on understanding and designing artifacts that sit at one boundary while Pina et al. and Murnane et al. are focused on describing social structures and collaborative tracking practices. In our research, we aim to bring together ideas from both lines of research, offering a deeper understanding of collaborative practices and artifacts at boundaries that exist within close proximity. Previous work noted the importance of aligning and communicating about goals (e.g., [10, 11]) and resolving competing commitments (e.g., [39]) in these collaborations. Our study highlights tensions that arise in the use of personal data when people have differing priorities—both among and within individuals.

2.3 Supporting Group Work in Sport

HCI research around sports has focused on designing novel technologies that support a specific sport (e.g., swimming [37] or squats [22]) and on facilitating social experiences around sport [28, 56]. HCI's examination of the social dimensions of sport technologies tends to see social features as a way to create accountability or motivation, such as through social fitness groups (e.g., [24]), games (e.g., [31]), or sharing (e.g., [13]), leading to behavior change.

Recent HCI research has studied the use of personal data and tracking tools by individual amateur and elite athletes [41, 51]. Some of this work touches on the importance of coaches in making sense of tracking data [41] or in the potential of data to support athlete-coach communication [22],

suggesting that the role of data in collaboration between athletes and coaches warrants further research. For example, professional soccer players described coaches as gatekeepers to the data: collecting, analyzing, and changing workouts based on the data all without the athletes ever seeing it. How do such uses support collaboration, and how do they alter the coach-athlete relationship?

Outside of HCI, research in sports psychology and sport science has recognized the importance of understanding the relationship among athletes, trainers, and coaches. Researchers have investigated dynamics across roles in sports teams, including the coach-athlete relationship [17, 26, 38, 53, 54], athlete pairs [40], and multidisciplinary collaboration among coaches and numerous support staff (e.g., team doctors, psychologists, physiotherapists, sports scientists) [42]. Common themes show that these partnerships and collaborations can experience healthy and unhealthy conflicts, but are successful when there is shared vision, open communication, and compatibility [17, 40, 42, 54]. Additionally, for the coach-athlete relationship, the coach is essential for managing conflict and creating an *autonomy-supportive* culture [26], where the athletes have a more positive view of the coach-athlete relationship, which benefits athlete motivation [26, 38].

Collaborations among these roles often include collecting, sharing, and reviewing athlete data [5, 44]. Research on the adoption and use of athlete self-report measures (ASRM) highlights the complexity of introducing new athlete data collection and interpretation tools into a team [44–47]. ASRM can facilitate communication and sharing of information between athlete and staff and among staff. However, athlete concerns—about who would see the data they shared, how it would be used, and that they or their teams would be punished if they did not provide their data to the ASRM—point to power asymmetries between athletes and staff and concerns about staff surveillance of athletes in the collection and use of athlete personal data.

The lenses of HCI and CSCW research are well-suited to examine challenges associated with use of athlete data in sports team collaborations. The experiences of individuals in sports teams also provide insight to the HCI and CSCW communities about the use of personal data in high stakes collaborations with power asymmetries between roles. Additionally, athletes and team staff sometimes do not align on their priorities. This offers a contrasting setting to previously studied patient-provider collaborations, in which patients and providers generally could align on goals, often facilitated by the use of personal data [10, 11].

3 METHODS

To understand how NCAA teams collect, collaborate around, and use data, we conducted 22 semi-structured interviews that focused on eliciting the perspectives of four different roles in an NCAA team. We interviewed 11 student-athletes (A) and 11 staff: three coaches (C), four strength and conditioning coaches (SCC), and four athletic trainers (AT). These roles, job titles, and responsibilities are consistent across the NCAA. Participants received no compensation for the study.

Three of the authors are former student-athletes and five additional research team members were student-athletes at the time of the study. We drew on this domain expertise for the design of the study, including recruiting and interview design. We also leveraged the domain expertise in the analysis and in presenting the findings, to include domain-specific context necessary for understanding our findings and their implications.

3.1 Recruitment

Being part of an NCAA team in any role usually means having little spare time because team practices and competitions, including travel for competitions, often dominate athlete and staff schedules. Therefore, individuals are unlikely to respond to calls for participation in research from unknown researchers, especially for a study not offering compensation [6]. Due to these expected

difficulties in recruiting from an already limited population, we recruited participants through the authors' personal and professional networks, student-athlete members of the research team reaching out to peers, and snowball sampling.

In our recruitment, where possible, we sought participants from different sports and of various competitive levels, including Division I and Division III of the National Collegiate Athletic Association (NCAA), each with differing amounts of funding, resources, and recruiting available. Also, having prior knowledge of the different roles within an NCAA team, we specifically targeted our recruitment towards the four roles in our study. The diversity in sport, institution, competition level, and role among our participants allowed us to develop a more comprehensive view of of the use of athlete data in NCAA teams.

Roles	Gender Distribution	Sports Distribution
Student-Athletes (A1-11)	7 female, 4 male	cross country running, gymnastics, rowing, track and field
Strength and Conditioning Coaches (SCC1-4)	1 female, 3 male	basketball, field hockey, lacrosse
Athletic Trainers (AT1-4)	1 female, 3 male	basketball, ice hockey, rowing
Coaches (C1-3)	1 female, 2 male	rowing, swimming

Table 2. Participant information by role.

3.2 Interviews with Student-Athletes (A)

To understand athlete experiences with tracking data and how they are involved in or perceive the staff's collaborations around their data, we conducted 11 semi-structured interviews with student-athletes (A). Of these student-athlete participants, seven were female, four were male, three competed in gymnastics, six in rowing, and two in cross country/track and field. All competed for the same university. The interviews ranged from 33 to 47 minutes (mean: 39 minutes). These interviews were all conducted by two interviewers, both students—one student-athlete and one Human Centered Design & Engineering (HCDE) student (the authors' affiliated department)—conducted each interview. Each interview was audio recorded with the participant's consent.

These interviews explored what athlete data are tracked, how these data are used, the effects of these data on the student-athlete experience, and their relationship with coaches and staff. Each interview started by exploring what information the athletes track themselves, what their coaches track, and how they or their coaches use these data. The focus then shifted to how data tracking, especially interactions with their coaches and staff about tracking data, affects their experiences as student athletes. The interviews finished with questions about how they feel about their information being shared among their teams, with their trainers, coaches, and with the public.

3.3 Interviews with Athletic Trainers (ATs), Strength and Conditioning Coaches (SCCs), and Coaches (C)

To understand how staff collect, use, and collaborate around data, we conducted 11 semi-structured interviews with five athletic trainers (ATs), five strength and conditioning coaches (SCCs), and four coaches (Cs) representing three universities. Of these 11 participants, eight were male and three

were female. They work most closely with athletes competing in basketball, rowing, swimming, and ice hockey. The interviews ranged from 33 to 100 minutes (mean: 48 minutes). Each interview was audio recorded with the participant's consent and conducted by the first author.

In these interviews, we explored the goals and responsibilities of each staff member, their practices for data collection and use, and how they collaborate with other staff members and athlete. Each interview started by gaining an understanding of each participant's job and how they collaborate with others staff members and athletes. Our focus then shifted to the types of information participants collect about the athletes and how they use it. The interviews finished with specific questions about their experience with or perception of tracking technology and how this affects their jobs.

3.4 Analysis

Our analysis consisted of a multi-stage, inductive process that moved from memoing about emerging themes, through a collaborative sensemaking exercise with our research group to develop an initial coding scheme, to a final stage of systematic coding and synthesis by two researchers. In each stage of the analysis, we leveraged the domain expertise of the authors and student-athletes on the research team to strengthen our understanding of the data and create new understanding in our analysis.

In a first round of analysis, researchers began by memoing about recurring and emergent themes, further developing those themes during transcription and then meeting to discuss insights. When all interviews were finished and transcribed, we used a grounded approach informed by Charmaz [9] to identify salient themes inductively—through an affinity diagramming [3] process that enabled participation by a team of 10 researchers, including five current student-athletes (researchers, not study participants). Affinity diagramming took place in two phases, one for each group of interviews. Each affinity diagram was constructed over several sessions with the research team. These sessions were followed by extensive memoing to synthesize insights and connect themes within and across the different sets of interviews.

In our first round of analysis, we identified collaboration and tensions around data, its collection, and use as major themes. This prompted us to conduct a second, more focused, analysis to identify collaborations and tensions around boundary negotiating artifacts. Two researchers systematically coded the interviews, using a coding scheme derived from the first round and from boundary negotiating artifacts. This scheme included codes for identifying boundary negotiating artifacts, participant goals, collaborative and data-supported activities, and tensions in collaboration, around data, and between individual and team priorities. We also conducted open coding, in parallel, to identify emergent themes.

After all the transcripts were coded, we conducted a final round of analysis in which we organized our data around boundary negotiating artifacts we identified and used our codes to identify patterns in collaborative practices around these artifacts, how they are used, and the tensions that arise. Finally the research team met to synthesize this analysis into an ecology of roles, goals, and artifacts and to discuss themes that emerged across artifacts.

We present our findings in three sections. Section 4 describes each of the four roles and their goals followed by a review of key artifacts created and used in collaborations among these roles. Sections 5 describes tensions associated with differing or competing priorities between roles and how that affects use of the artifacts. Section 6 describes power asymmetries around collection and use of data that highlight issues of agency, privacy, and surveillance. Within each section, we present findings followed by discussion.

4 DEFINING THE COLLABORATIVE ECOLOGY OF NCAA SPORTS TEAMS

In this section, we first describe the four roles of NCAA teams that we studied—student-athletes, sports coaches, athletic trainers, and strength and conditioning coaches—and their shared goals. We then use the lens of Boundary Negotiating Artifacts to describe artifacts that use athlete data and are involved in thee collaborations. This ecology provides important context about the roles, goals, and collaborations within collegiate sports teams and begins the discussion of tensions that surface in these collaborations.

4.1 Roles & Goals

The overarching goal for any sports team is to win competitions: in particular, a final competition, usually called the championship. Winning is supported by four more specific goals that participants described focusing their efforts around: 1) **Maximizing performance today** to win competitions, 2) **Improving performance** to win future competitions, 3) **Injury prevention** to keep athletes healthy for the sake of their own well-being and so they can contribute to the team's success, and 4) **Injury rehabilitation** to return athletes to a healthy state so they can contribute to winning competitions. Staff (AT, SCC, and C) discussed all four goals, while student-athletes only explicitly discussed maximizing and improving performance. Together, actions taken towards these goals are intended to give the team the best possible chance of success. However, each role may prioritize these goals differently in ways that conflict or make it difficult to work towards a goal.

Drawing on our research team's contextual expertise and our interviews with participants, we describe each of four roles within NCAA teams and the actions they take towards these goals:

A **student-athlete (A)** is an athlete who attends college while practicing and competing with a team [55]. Teams differ by sport and athletes differ by position or individual strengths within that sport. In general, the athlete's goal is to maximize and improve their individual performance while contributing as much as possible to the performance of the team. Although athletes are taught to value the success of the team over individual success, they are also in direct competition with their teammates for positions on the team. In pursuit of both individual and team goals, athletes are often driven to participate as much as they can, even if they might injure themselves.

Each team has at least one **sport coach (C)**, who is the main decision-maker and leader of the team. Coaches are responsible for the team's performance and consistent loses would be blamed on the coach, so their main goals are maximizing and improving team performance. To be successful, they endeavor to enable their team to win by training their team to be as fit and skilled in their sport as possible. Coaches often face a tension of prioritizing the team over individual athletes in their decisions [54].

Athletic trainers (AT) play a key role in a sports team as "facilitators of healthcare" (AT3, AT4), meaning they are responsible for the physical and mental well-being of the athletes on their team. This responsibility includes being the authority on decisions regarding the management of athlete injuries. Though they are not doctors (team doctor is a different role), ATs have advanced professional training that allows them to treat acute injuries, rehabilitate previous injuries, and prevent future injuries. Their main goals are effective injury prevention and rehabilitation to keep individual athletes healthy, which contributes to the team's success.

The role of **strength and conditioning coaches (SCC)** balances all four goals as they are responsible for helping athletes become as fit, strong, and resilient to injury as possible—e.g., through strength training (with weights) and conditioning (cardiovascular fitness activities such as running)—as well as coordinating modified strength training for injury rehabilitation with the AT. Though SCCs work closely with ATs, their roles are distinct—their day-to-day responsibilities are different and they undergo different levels of training. Additionally, with the influx of new tracking

technologies, a person in this role is now expected to use these tools to assess their athletes' overall ability to perform.

4.2 Collaborations supported by Personal Data and Boundary Negotiating Artifacts

Looking at our data through the lens of boundary negotiating artifacts, we identified six different artifacts covering all five types of boundary negotiating artifacts. Each artifact mediates a collaboration between two or three roles at at time. An artifact that mediates more than one micro-collaboration may be more than one type of boundary negotiating artifact and its type at a given time depends on the context and use.

We describe the six artifacts we identified and the collaborations around them in sections 4.2.1 through 4.2.6 followed by a discussion of power asymmetries around and between these artifacts in section 4.3.

4.2.1 Injury Report. The **injury report**, described by AT1, AT4, C3, SCC2, and SCC4, is a *compilation artifact* created by the AT. The AT compiles team and injury information and organizes it using tools such as Microsoft Excel, Google Sheets, or team management software (e.g., FrontRush). The injury report lists the team roster, the injury status of each athlete, and notes pertaining to the training limitations for each athlete (e.g., *"no upper body"* (SCC2)). The AT shares the injury report on a daily or weekly basis with the SCC and sport coach in whose context it transitions from *compilation artifact* to *structuring artifact.*

In the initial act of sharing the document, the AT passes crucial information to the other staff, and sharing initiates informal conversations between the AT and SCC and the AT and sport coach in which conflict is resolved and their goals and understanding are brought into alignment. Specifically, staff will negotiate what athletes can and cannot do in training sessions and come to an agreement (AT1, AT3, AT4, C3, SCC4). For example, C3 describes a conversation with an athletic trainer:

> *There is a back and forth and they asked me like, well this is the issue, this is the range of motion, these are the things that they can't do or they're in pain. Let's figure out what other ways that they can stay with the team and stay fit.*

Following these conversations, or when negotiation is not needed, the injury report is a *structuring artifact*: through this artifact, the AT directs the activities of SCCs and coaches, directing the modification of training for injured athletes. Thus, creating and sharing the injury report aligns with the AT's main goals of injury prevention and rehabilitation. As a structuring artifact, the injury report, like the athletic trainer, holds a unique place of authority for the decisions regarding an athlete's training while injured.

4.2.2 Wellness Data. Staff both formally and informally collect **wellness data** from athletes. This includes any non-performance information, such as sleep quality, fatigue, soreness, stress, and mood and can be collected through observation, self-report, and sleep tracking devices. The goals of collecting this information are to prevent injury and improve performance. Wellness is intertwined with performance so considering wellness data supports staff in effectively training their athlete and avoiding injuries (AT1, C2, SCC1).

Formal collection of these data happens through a daily wellness survey or questionnaire (A1, A2, A3, AT1, AT2, SCC1, SCC4). A2's team uses an app called TeamWorks to manage the survey; she and her teammates fill it out before practice each day. Some teams augment the self-report data with personal tracking devices, such as sleep trackers (SCC1, SCC4).

Informally, sport coaches, SCCs, and ATs also gather wellness data through observing athlete behavior and striking up conversations with athletes. Cultivating this relationship with their

athletes helps staff to see irregularities (AT2, C2). AT1 and C2 both describe this informal gathering of information similarly as their way to keep a "pulse" on the team (AT1, C2).

The nature of the procurement of wellness data makes them a type of *borrowing artifact*. As Lee wrote on borrowing artifacts, "the concept of borrowed artifacts is focused on the procurement of an artifact and not its creation" [23]. Whether collected formally through surveys or devices or informally through interactions, wellness data are borrowed, taken from the athletes with the athletes' knowledge. It is worth noting here that though the athletes may know these data are being collected, they may not have have a choice about letting these personal data be extracted from them.

As borrowing artifacts, wellness data are augmented and used in unanticipated ways, sometimes as another type of artifact. Staff described augmenting wellness data with injury reports (section 4.2.1), objective measures (section 4.2.3), or both at once 4.2.5.

SCC4 described creating an *inclusion artifact* where performance data are augmented with wellness data when he shared information about an athlete's personal life to explain an athlete's recent performance to the sport coach:

> *Anything has to do with performance is under my umbrella and then me and the head coach sit down and we'll talk. 'I heard so and so broke up with his girlfriend, just a heads up, you know, he's been off lately.'*

As for how wellness data are used in an "unanticipated way," we define unanticipated from the perspective of the borrowee, in this case the athletes. Therefore, to know if athletes are able to anticipate the use, we need to examine uses of wellness data and how athletes think they are is used. Also, in some examples, wellness data may appear, to the reader, to be used in an anticipated way, to achieve the staff's goals. However, Lee's example of a borrowing artifact is described as being used "to further the goals of the project". Therefore, the use of borrowed artifacts to further a goal qualifies as unanticipated in the lens of boundary negotiating artifacts.

In addition to the use described by SCC4, AT2 describes making a last-minute decision prior to training to protect an athlete's well-being based on wellness data:

> *Like if they look exhausted, you talk to them, they haven't slept, they haven't been eating, they've had an injury, then I find a way so they don't train.*

SCC2 also described how a sport coach uses reported soreness to inform training so that the athletes are not overworked:

> *[The coach] has in mind how each session should be: hard, medium, or light. After a hard day if the guys say their soreness or fatigue is low, then that means he didn't go hard enough and next time he can go harder. Now if it's supposed to be a light day and the next day the guys are sore then he knows he needs to back off.*

Despite having some knowledge of how all the other artifacts are used, only A1 was able to anticipate any of the use cases for wellness data. A1 describes an example similar to SCC2 (SCC2 does not coach A1):

> *I think it's just to gauge practice, so if everyone's consistently putting ones for soreness, they probably dial it back a little bit. I don't know if they would decrease our amount of practice if less people were like getting sleep or feeling more stressed or something.*

A1 understands that the wellness data could affect practice, she anticipates a reduction in training intensity if the team is sore, stressed, or not getting enough sleep.

Neither A1 nor any of the other athletes anticipated any of the other uses, and if an athlete does not know how the data is used, any use could be unanticipated. A2, A3 and A6 all described not

having access to their collected wellness data or knowing how staff members were using it. A3 specifically states:

> *No we submit it, we don't get to see the trends which is kind of unfortunate... So I don't know how [the coaches] use it.*

In this way, Lee's definition of borrowing artifact characterizes wellness data and their use. However, as we will discuss in section 6, there are also power dynamics involved in the creation of these artifacts that are not made salient by the current concept.

4.2.3 Performance Data. Though **performance data** have long been collected through observation in training and competition, participants discussed using a myriad of tracking devices to collect time, distance, pace, elevation change, GPS, calories, steps, acceleration, cadence, muscle activation, heart rate, and training load (training load refers to both internal measurements, the physiological and psychological stress of training, and external measurements, such as duration, speed, and acceleration [5, 7]).

Participants described experiences using seven different performance tracking devices. These experiences were mainly within the team context, where the team provided the devices and accompanying software (only A6 owned her own watch device). All seven are wearable devices: sensors worn on an athlete's body during training—e.g., a watch, chest strap, sensor built into a shoe, or a screen worn on an athlete's shirt. These wearable technologies mentioned are Polar [52], Catapult [8], Zephyr [29], Zebra [32], Athos [2], and FitBit [14]. These products monitor different values and differ in their intended uses, so some teams use more than one device. Polar, Zephyr, and FitBit monitor an athlete's physiological data such as heart rate, and Catapult and Zebra monitor an athlete's precise physical movement using accelerometers and gyroscopes. Athos differs from the others; it measures muscle activity using sensors in specialized clothing.

When athletes are tracked by any of these devices during training, the staff and sometimes the athlete can see real-time data (HR, muscles firing, other performance information). Watches, in particular, enable athletes to see real-time information at a glance. This contrasts with wellness data, which athletes are not able to see other than when they report it. However, in the case of Catapult, Zephyr, or other chest-worn devices, only the staff can see the data in real-time and they are shared with athletes only when staff choose to do so (we describe this briefly below and discuss it further in sections 5.2 and 6.2).

Data collected by these devices are reviewed and used in several contexts, corresponding to three different types of artifacts:

(1) When an athlete reviews their own data in real-time or after the fact (described by A6, A7, and A9), the data are a *self-explanation artifact*. Only one athlete, A6, described owning her own device and could thus review her data at any time.
(2) When a staff member collects these data, they are a *borrowing artifact*, as these data, similar to wellness data, are taken from the athletes. In this case, the borrowing is automatic and mediated by the device. These data are then transformed into other types of artifacts when staff organize and share data.
(3) When a staff member organizes and reviews the data in real-time or after the fact, these data are a *self-explanation artifact* (AT1, AT2, SCC1, SCC4).
(4) When an athlete and a staff member review the data together or staff members review the data together, the data are an *inclusion artifact* (section 5.2.1). This designation is appropriate because the *self-explanation artifact* afforded by the device is reshaped into an *inclusion artifact* through discussion where new ideas or understanding is created. Participants also

described *inclusion artifacts* from these discussions being incorporated into two *structuring artifacts*, the one-sheeter (section 4.2.5) and the training plan (section 4.2.6).

Participants cited all four goals in the use of these artifacts. For example, these artifacts can be reflected upon or used to identify trends or patterns that can be used to maximize and improve performance and manage injury rehabilitation (AT1, C2, SCC1), and, specifically, injuries can be prevented by using these artifacts to monitor training load (AT1, AT2).

4.2.4 Training Log. Athletes and their coaches both contribute to creating the **training log**, a *compilation artifact*. This training log is a compilation artifact created through the compilation and organization of information from several sources, including athletes, staff, and sometimes devices. It is used to pass important performance data between athletes and staff and foster understanding between the roles. In contrast to the other artifacts, both athletes and staff can view the training log.

Each team selects their own format for the training log; for example, Google Drive (especially Google Sheets), Microsoft OneDrive, and TrainingPeaks were commonly used. On two teams, athletes were responsible for compiling, maintaining, organizing, and sharing the training log with their coach (A5, A6). Additionally, C3 explained that his athletes care about their data and correct him if he makes a mistake when adding their data to the log (C3).

Several participants described that by compiling the training log, they hoped to support reflecting on past performances and use trends to inform decisions about training session and competitions, ultimately improving performance (A6, A8, C2, C3, SCC2). For example, C3 describes using the times recorded from weekly tests—time trials where the swimmers are timed for a set distance—to get an indication of how training is going and if his plan is working:

> *[The tests are] assessing the effectiveness of the training program and our training cycles. So if I can tell if they're improving from test to test, then the training's doing what we wanted to do or if they improved from test one to two and then they might stay the same from two to three, that's okay. But if they're getting worse, that's an indication that they're being overtrained.*

C4 then uses this information to modify his training plan and learn from it to improve his plans in the future.

4.2.5 One-Sheeter. ATs and SCCs work together to filter information they gather from athletes and decide what to send to the coach. They do this because it is part of their role to inform the coach of matters where the coach may not have knowledge or expertise or to which the coach is disinclined to pay attention (AT1). Additionally, the information must be filtered and simplified because the AT and SCC know that the coach has very little time to consider the information they provide, and that the coach can ignore or fail to absorb their information, especially if it is too complex—hence the **one-sheeter**:

> *[Me] and the athletic trainer can look and dive into the nitty gritty details. The coach needs it to be a one sheeter quick hitter... Really, really simple to understand. They don't need to know every minute detail of our data because to them it gets lost and it loses value. Can they go hard today or can they not? (SCC4)*

SCC4 and AT1 described other types of short and simple information as, for example, when speaking about an individual athlete's participation: *"yes, no, green, red," "they can play or they can't," "they can be in this drill,"* and, when speaking about training intensity: *"back off, ramp it up, or we're doing good."*

Despite aiming to deliver a small amount of information to the coach, ATs and SCCs have to consider a lot of information themselves. They consider health data regarding an athlete's physical

and mental well being, including injuries and information about their personal life. They also consider performance data regarding how much stress recent training and competition has put on an athlete's body. Plus, they have to consider this information for each individual and aggregated for the team, which AT1 describes as a *"huge challenge."*

ATs and SCCs draw on the other artifacts and any other information or expertise they have access to outside of these artifacts, to create a *structuring artifact*, the one-sheeter. This is where wellness and performance data as *borrowed artifacts* are transformed into *inclusion artifacts* when the AT and the SCC filter the important information and into a *structuring artifact* when they become part of the one-sheeter. As the one-sheeter may include simplified information from the other artifacts, it can be used to negotiate training (as it serves improving performance), injury prevention, and injury rehabilitation. Additionally, the one-sheeter, supported by the AT and SCCs council, is a counterbalance to the coach's authority as it has the power to influence the coach's decisions.

4.2.6 Training Plan. A common idea throughout our data, across all roles, was that the data that teams collect is valuable because it informs decisions about training. In other words, the purpose of the five artifacts we have described so far—the injury report, wellness data, device data, the training log, and the one-sheeter—and the collaborations around them is to make data-driven decisions about a sixth artifact, the **training plan**. Created by the coach to serve the overarching goal of winning, the training plan is a powerful artifact; creating the training plan is all about creating an effective plan that will result in maximized performance for competitions and improved performance over time so performance is maximized for future competitions.

The training plan is a *structuring artifact*: the sport coach creates and distributes it to athletes, ATs, and SCCs to direct and coordinate their actions. For example, the training plan structures when and what athletes will do for training, what decisions ATs make in regards to modifications to training for athletes who are rehabilitating from injury, and how SCCs structure their strength training. This distinguishes the training plan as a *structuring artifact* rather than a *compilation artifact* because it is directing the actions of others. However, the training plan is not a static artifact, it is in flux as it is affected by the other artifacts and collaborative work being done around them.

Sport coaches, ATs, and SCCs use the injury report to decide which athletes are able to participate in training and collaborate to determine specific limitations for each athlete and modify the training plan for injured athletes. Also, AT4 describes that the injury report results in modifying the training plan for the whole team if there is a common injury across multiple athletes. Additionally, staff use wellness data, including observational data, the self-report survey, and sleep trackers, to modify the training plans for individuals or the team.

Similarly, staff described using performance information to modify (e.g., change training intensity, restrict training, or increase rest time) team training and individual training (AT1, AT2, C3, C4, SCC1, SCC2, SCC4). Both the device data and the training log represent information about past performance that can be used to make modifications to the training plan based on trends in team or individual performance, such as C4 described in section 4.2.4. These trends can be from information collected daily or at strategic intervals (e.g., once a week, a month, a year). For example, AT1 and SCC1 use device data, specifically load, to know if the team is training too hard and may be at risk of over-training and injury, which would necessitate modification to the training plan to include more rest in the current week:

> *What does the last week you just did look like compared to the previous four weeks? The acute week compared to the chronic week. And there's a range of a 0.8 to 1.3 that's a safe zone, anything above 1.5 puts you at 2 to 3 to 6 times risk of injury for the next three to four weeks. (AT1)*

Here AT1 describes how he uses load, collected for every training session, to figure out when his team is safe and when they are at a greater risk of injury. Using this information he can *"tell the coach to back off or ramp it up or we're doing good"* so the coach can modify training accordingly.

4.3 Discussion: Power asymmetry and its role in boundary negotiating artifacts

Previous research on boundary objects [50] and boundary negotiating artifacts [23] implies the role of power that either people or artifacts hold and how power dynamics affect collaborative efforts. Lee describes how two structuring artifacts were in conflict until one took precedence as the dominant structuring artifact [23]. As one became more powerful than the other, the creators of that artifact had more power in the collaboration as their artifact structured the direction of the group's work moving forward.

Power is similarly implicit in our data, and power dynamics are latent throughout. In describing the collaborative ecology of sports teams, a hierarchy of roles becomes clear. Athletes are often at the bottom of the hierarchy, despite being most directly involved in a team's success in competition. SCCs and ATs work with athletes to maintain and improve their health, but their role as intermediaries with the coaches gives them other avenues to assert power. Sport coaches (and especially head coaches) have the most influence over the team's actions, though their control may vary across context. For example, the coach may hold the most power and influence in team practice and competitions, but in a medical context, where the coach has little expertise, the AT's training and expertise can overrule the coach.

Power asymmetries across a team's hierarchy affect the creation and use of the boundary negotiating artifacts we identified. As in personal health data [33], the data and artifacts in our study often mediate representations of the individual athletes to the staff and even to other athletes. Our work shows how these data are not only presented by the individual—in this case the athlete—but how other roles, or layers in the hierarchy, also borrow or extract that information from individuals to support their work. Once collected, staff may share that information with other members of the team, as we see with the example of the training log.

Among the staff, where there is a less significant power asymmetry, coaches ultimately hold a lot of power because they control and have a final say in decisions about the team and training. SCCs and ATs use the one-sheeter to challenge the coach's power, but the coach can choose to follow their advice or not. They learn if their advice was heeded when the training plan is communicated to the staff; ATs and SCCs must then adjust their own plans for strength training and injury rehabilitation accordingly (AT3, SCC2). Staff describe rarely challenging a coaches decision. When they do, it is most often done by the AT an through the injury report. This power check illustrates the AT's unique role on the team as AT's are supposed to have unchallenged and "autonomous authority to make medical decisions in the sole interest of student athlete health and well being" [34].

Though we did not specifically design our interview protocol around power dynamics, we found evidence for the role of power and its connection to artifacts is across our results. The next two sections examine tensions across roles and artifacts, some of which emphasize who holds power and how power is embedded in a team's structure.

5 OPPORTUNITIES FOR DESIGN: HIGHLIGHTING TENSIONS AND BARRIERS IN COLLABORATIONS AROUND BOUNDARY NEGOTIATING ARTIFACTS

Collaborations using boundary negotiating artifacts in collegiate sports teams are complex and nuanced. These collaborations are generally cooperative in pursuit of the collective goals of improving and maximizing team performance and preventing injuries. However, tensions arise in which these team goals compete with individual goals, such as improving individual performance or rehabilitating an athlete's injury.

In this section, we describe the role of boundary negotiating artifacts in coordinating among differing priorities between staff members or between staff members and athletes. We also describe how the current artifacts support collaboration and how they do not, leading to a discussion of opportunities for design around these artifacts and collaborations. Though many of these collaborations occur without conflict, we present tensions surfaced by the use of self-reported and tracked data to discuss opportunities and considerations for the design and adoption of tracking tools.

5.1 Different priorities of individual and team goals can be a source of tension among staff members

Staff find they can collaborate well when everyone's goals—injury prevention and improving performance—are aligned and when they have the necessary information to support good decision-making. For example, AT4 describes using the injury report to advocate for the whole team if they notice multiple injuries of the same type:

> *So if I have muscle injuries or a couple of guys are getting hip stuff or a couple of guys are getting shoulder stuff, you know tendinitis, things like that, that's the preventables, that's where I could say "hey, I think we're doing too much overhead" or "hey, we're doing too much single leg stuff we need to modify, we need to examine what we're doing in the weight room in order to make sure that we're not putting these guys [at risk of injury]."*

In this example, guided by his responsibility of preventing injuries, AT4 noticed a pattern of injuries in the data and advocated on the team's behalf to the SCC and sport coaches. Preventing injuries is the AT's priority, but it is a shared goal; prevention of injuries that could result from a problem with the training plan also supports the SCC and sport coaches' priorities of improving individual performance and maximizing team performance. Thus, when AT4 suggests changes to training that will protect the team from injury, the other staff generally value and act on such guidance.

In contrast, tensions can occur when the goal of supporting an athlete's rehabilitation competes with the goal of maximizing team performance in a specific event. AT3 describes push back from a coach after a reporting an athlete is not able to play due to injury:

> *That's a difficult part of this job, a lot of time you're conveying bad news... I'll get "he's soft" or "he can play through that" and I'm like alright but he's not going to play. I think some of that is just frustration that they have somebody out because obviously every coach wants every athlete to be at 100 percent at all times. They expect that and it's just not going to happen.*

In the situations that AT3 described, the coach was upset and pushed back because this athlete was part of the coach's plan to maximize team performance in an upcoming competition. When an athlete cannot play, this can jeopardize team performance. While playing an injured athlete for the benefit of the team may seem irresponsible, it is a tension for coaches and for athletes themselves: many athletes want to play to maximize short term success, even if it comes with risk of injury or slower recovery. Legendary sports stories—Michael Jordan playing with the flu so the Chicago Bulls could move on to win the NBA Finals or Jack Youngblood playing with a broken leg through the NFL playoffs—show that the risk may be worth the reward if it would help the team win a playoff or a championship competition [4].

Within the NCAA, teams are required to follow a model of medical care in which the AT prioritizes individual athlete health and safety over other priorities and has authority over medical decisions. However, in a recent survey of NCAA ATs, half of the respondents reported not following the NCAA model of care. Additionally, a sixth reported experiencing pressure to *"make a decision*

that was not in the best interest of a student-athlete's health" [34]. Based on our interviews, some of this tension results from the inherent uncertainty of decision-making, and that an individual's priorities may cause them to read that uncertainty differently.

Though all roles hoped that data from self-report and devices can better inform the decision to rest or play an athlete, the data and our current knowledge of how to interpret them rarely provide certainty. However, participants in our study reported some situations in which personal data and the boundary negotiating artifacts created from them, prompted an AT to take action and helped provide support for the AT's decision to protect a student-athlete's health. In the example from section 4.2.2, AT2 was motivated to *"find a way"* to make sure an athlete does not train if wellness data indicate that an athlete needs to take a break and rest.

Similarly, device data can help an AT feel more confident in their injury rehabilitation decisions. AT1 and SCC1, who work with the same men's basketball team, described using device data to give the coach an exact quantification of how much an athlete should train while recovering from injury:

> *We had a guy this year, we used [the device data] a lot for return-to-play because we had baseline numbers of things he did before he got hurt and once he came back... we literally had it down to the steps, the amount of jumps, to the load, it was really helpful.* (SCC1)

> *So if I knew he was going to go 3000 steps today, next week I know he was going to do 3300 and on and on...we could say to coach at practice, he's 50 percent of the way there, he's 75 percent of the way there, he's 90 percent of the way there...for a long time it used to be well, he's got 45 minutes. Well is that 45 minutes all together? Is that 45 minutes over the course of the two hours?... As long as we have baseline data upfront then we can more precisely manage and not guess.* (AT1)

This more precise data and communication—the creation of guidance as a structuring artifact—gave AT1 confidence in his decisions and that the coach and athlete would follow them in training.

5.2 Tensions and Barriers in Collaborations Between Athletes and Staff

A good relationship between athletes and staff, earmarked by trust and effective communication, is important for success, including both individual and team athletic performance and individual well being [18]. However, athletes individual priorities and barriers faced by staff can create tensions or limit potentials for further collaboration.

5.2.1 Athlete priorities can be a source of tension with staff members. At first, staff goals of using device and self-report data to maximize performance and prevent and rehabilitate injury seem well-aligned with athlete goals of performing well and staying healthy. However, performance and staying healthy are only a subset of a student athlete's priorities; a more complete understanding surfaces potential tensions.

For example, similar to tensions between coaches and ATs, athletes who are injured may want to play through their injury [25], putting athletes into conflict with the AT whose job it is to protect athlete well-being, even from themselves. Athletes have many reasons for prioritizing competing over their own well-being, such as love of the sport, desire to be on the field, helping the team, sacrificing themselves to win a game, and that playing through injury is an accepted behavior [25].

A11 described a time when he disregarded early signs of injury. His coach and AT picked up these signs through observation (back pain) and from device data (elevated heart rate or a high training load). His coach and AT wanted him to sit out, but A11 convinced them to let him continue training and competing:

> *They were telling me because of my back that I should stop, or take time off, but I felt like its not as bad as they think it is or whatever, I don't remember exactly what I told them, but basically I just convinced them to let me keep going.*

He eventually sustained a serious back injury, was seen by a doctor, and had to take time off. Scenarios like these frustrate AT4, who described many athletes coming to him complaining of chronic pain or an injury that has existed—and worsened—for months before the athlete decides to seek help. Literature even describes athletes asking ATs or doctors to lie or keep an injury a secret so that they can keep competing [42].

Athletes also spoke of the opposite scenario: feeling fatigued or in need of a break, but being unable to convey the seriousness to their coaches. A1 noted *"the only time we get sent home is if we're throwing up sick,"* i.e., when there is a visible and disruptive problem. A1 wanted to protect herself and prioritize her health, while her coach strives to keep her training consistent. However, if an athlete's self-assessment is not taken seriously in deciding what to do, the more visible evidence may be too late to prevent more serious injury. A2, a teammate of A1, believes that device data could support how she is feeling and help her communicate to her coach in a way that provides evidence for action:

> *You know when you're fatigued and you know when you're feeling good and I think the wearable technology can help reinforce that and it can also help with the coaches because the coaches don't know, they can't read your body completely. And so if that matches how you're feeling, it might be easier to communicate and for them to believe you.*

A5 similarly wanted his coach to know when he was putting in effort and which of his teammates were not; A5 believed that heart rate data could provide better insight into this than coaches' observation could alone.

AT1 and SCC1's use of data to quantify training (section 5.1) suggests that device data may offer such insights. However, none of the athletes in our study discussed successfully using data in this way, perhaps because they did not have access to the data or the expertise to interpret it as AT1 and SCC1 did.

Where staff and athlete priorities aligned around improving performance, staff found device data useful for facilitating teaching moments with athletes. For example, AT1 describes using performance data as an *inclusion artifact* to help athletes better understand their limits and levels of effort:

> *We can show an athlete that when they feel like they've given everything and it looks like they've got more to give or yes they really have given max effort, we can show them what it feels like.*

Through reviewing this data together, AT1 works to help athletes learn the actual effort that corresponds to their perceived effort, so that they can more reliably train at the level directed by the coach or training plan.

5.2.2 Time constraints, and ability to interpret data limits collaboration between athletes and staff. Previous research notes that athletes may misinterpret wellness and performance data, drawing errant conclusions, if not supported by professionals [45]. However, staff in our study also noted that they may not have the expertise to analyze all of the self-report and device data they collect, and they can find themselves overwhelmed (AT1, AT2, SCC1): *"We have so much information we could be doing so much more with... People who are doing this the most have [their own] staff"* (SCC1). This suggests a need for both additional training and resources to fully understand and use the data.

The training log offers one example of the athletes being able to put in the time, even if the staff cannot. Though athletes spend time adding their data to the training log or curating it, their coach may not add the data they collect to the log, show they have seen it, or reliably use the data to adjust their plan. A6's coach requires her team to add comments to their data in TrainingPeaks to get athletes to reflect on their performance, but A6 is frustrated that her coaches rarely respond: *"[The coaches] get an email every time we update or write anything inside the log but they rarely view the emails or respond. Unless you're really special."* Though this may be due to coaches' time constraints, athletes perceive the limited replies as disinterest or favoritism.

In the case of the wellness surveys, staff collect the data, but athletes do not see that data again once they send it: *"We submit it, but we don't get to see the trends which is kind of unfortunate..."* (A3). As a result, athletes do not have the opportunity to reflect on and analyze their own data or to use that data to initiate conversations with staff about how they are performing or responding to training. The responsibility for interpreting the data and initiating conversations is left to staff.

Athletes also have limited access to data collected using team devices. Among our participants, all team devices transmit data directly to a team dashboard, where the staff can view it; they do not have interfaces for athletes to view the collected data. Consequently, when athletes wear a team device, the staff are gatekeepers of these data and athletes are only able to see it when staff share (AT1, SCC4). Sometimes athletes do ask to see the data, starting a conversation. A10 describes asking to review the data and the limits of that review:

> *If I want to go see the data I could go talk to one of my coaches and say like 'Hey can I see my past 3 workouts?' and they'd be like here, yeah. And take a look at it with me. But I don't have my personal data at home.*

When staff are the gatekeepers to both device and self-report data, this puts the job of understanding and acting on data on the staff rather than framing interpretation and action as a shared priority of both athletes and staff. This is unfortunate, because—as shown in 5.2.1—sharing data with athletes can result in a better shared understanding between staff and athletes.

In contrast to data collected by teams, athletes who have their own devices can review the data at any time. These athletes describe how seeing their own data and reflecting on it can help them understand their performance and training:

> *It's nice to look back later and you can track your run on a map where you can look at elevation gain and loss and how your cadence changed. (A6)*
>
> *[The device data] gave me a better sense of what I was actually doing... why I felt so exhausted and why I felt good from day-to-day. (A8)*

Given the positive experiences athletes can have with their own data, there is lost potential when athletes do not have the opportunity to review data that the staff collect, either on their own or with staff. Overcoming barriers to collaboration could create more opportunities for staff and athlete to collaborate productively.

5.3 Discussion: Designing to addressing tensions around differing priorities and overcome barriers in collaborations using personal data

Throughout their collaborations, staff and athletes use personal data and boundary negotiating artifacts that include these data to inform decisions, coordinate actions, and balance priorities. In collaborations between staff, conversations around these data and artifacts can help align priorities, leading to agreement about plans for individual and team training. In collaborations between staff and athletes, conversations around performance data can lead to shared understanding, leading to improved performance. Additionally, our findings describe challenges and opportunities for further facilitating these collaborations by supporting boundary negotiating artifacts in design.

In section 2.2, we introduced research on the use of personal data to support collaborations that further individual health and well-being. The previous research identified a lack of communication about goals—and resulting misalignments between goals—as a key barrier to successful collaboration [10, 48]. Our findings in sections 5.1 and 5.2.1 similarly describe tensions when goal priorities are not aligned.

However, our findings also describe successful collaborations where the goal priorities are aligned and ways personal data can support coordination and alignment of priorities. For example, personal data can reduce uncertainty in decision-making for ATs, which helps them collaborate more effectively with the coach.

Previously, researchers have proposed designs that help patients articulate their goals, so providers can tailor tracking and management plans to those goals [11]. Here we suggest some ways researchers and designers might facilitate successful collaboration around personal data on teams.

Section 5.2.2 describes how data overload, lack of time, and lack of resources for analysis are barriers to collaborations between athletes and staff around personal data. Overcoming these barriers could create more opportunities for staff and athletes to collaborate productively. For example, if staff are able to harness and analyze the data they have more swiftly into *self-explanation artifacts* for their own understanding, they would be able to use it to further their goals and have more time to discuss the implications of the data with athletes. Additionally, finding ways to support the review of data asynchronously, making it easier to share the data (e.g., importing it directly to the training log) could create more *inclusion artifacts* that could bring together the athlete and staff perspectives. Also, if staff could easily create *inclusion artifacts* based on the data to provide feedback to all their athletes, then all athletes could benefit from the data collection and the staff could have even more time for discussions with athletes. Finally, when staff are not able to analyze the data, returning it to athletes for their own reflection and analysis, with appropriate scaffolding, could create new opportunities for *self-explanation.*

However, we also find situations when goal alignment may not be possible. For example, both staff and athletes face dilemmas about whether a star athlete should play or sit out a key competition when they are at a heightened risk of injury. In such cases, researchers, designers and practitioners should instead consider how to support the team or the individual actors in coming to a decision that not everyone will agree on. For example, an *inclusion artifact* that uses the athlete's data and predictions for the teams performance to brings together the staff and the athlete to weigh the risks of the athletes participation against the benefits to the team. Or, similarly, a *self-explanation artifact* that supports the athlete in weighing their options on their own.

As personal data are increasingly used in collaborations, researchers and practitioners need to continue to develop new guidelines and design patterns that help individuals and groups make effective use of these data and artifacts that include them. For example, we might emphasize the creation of inclusion artifacts that help bring together and balance multiple perspectives.

6 AGENCY, EXTRACTION, AND SURVEILLANCE IN ATHLETE—STAFF COLLABORATION

To help manage and navigate competing priorities, athletes have often been selective about what personal data they disclose to staff and how. In this section, we will discuss how the adoption of devices that automatically collect and report data disrupt these previous practices, increasing issues of surveillance and power asymmetries. This leads us to propose an extension of borrowing artifacts—*extraction artifacts*—that makes the power asymmetries in the collection and use of boundary negotiating artifacts more salient.

6.1 Tracking changes athletes' ability to manage what they share and how they present themselves

Staff want ample and accurate wellness information, as it helps them train their athletes and avoid injuries (AT1, AT2, C2). Athletes also value wellness information because it is intertwined with performance (A3, A8, A11), and they know that providing their staff with this information can help them better understand their performance.

Though tracking can provide information that informs decisions and can result in benefits, the automatic collecting and sharing of athlete data also diminishes an athlete's ability to control what they share and how they present themselves. For example, athletes worry that information could affect their status on the team, if and how hard they train on a given day, and whether they compete. Wellness data that reveals violations of team rules or expectations—e.g., not getting enough rest—can also result in punitive actions for individuals or the team.

Experiences with sensed sleep data highlight some of these trade offs of tracking. Athletes have many reasons for not getting enough sleep, such as schoolwork, difficulty adjusting from travel, or wanting to spend time with friends. However, being short on sleep can both affect performance and increase risk of injury. If an AT or coach believed that an athlete was at risk for injury due to lack of sleep they may keep that athlete from practicing or competing.

In practice, however, athletes routinely do not self-report the most precise or accurate information about their sleep. To do so would mean that going to a party with friends or staying up late finishing a course paper would risk their standing on the team. From solely a safety and performance perspective, accurate self-report or pervasive, objective monitoring of sleep may appear desirable. Student-athletes, however, have many priorities beyond performance. A3 describes how she and her teammates distort their sleep on the wellness survey to maintain their status on the team while participating in the other parts of their lives:

> *A lot of us don't truly, honestly, fill it out properly. Like if we don't get enough sleep, we're not going to be like, "oh I got three house of sleep" because if we have a shitty practice they're going to be like "you should have slept more" and I'm like well…*

Across many conversations and ways of reporting data, athletes similarly carefully manage the information they disclose. This is easiest in conversations and self-report instruments, where they have the most ability to shape what they share. Sometimes athletes distort or selectively share information to avoid specific negative consequences (e.g., being kept from competing), while other times these distortions have a more general goal of saving-face or impression management, recalling the idea of a "Front" from Goffman [15]. Athletes in our study noted that the increased use of tracking data makes it harder to shape what they share.

Sometimes data lead to disclosures athletes do not desire but that are ultimately beneficial. A8 described a time when their coach noticed a difference in their performance, which led to a discussion and the athlete revealing that they had been taking antidepressants. She did not initially reveal this to her coach because she did not want this to negatively affect her coach's decisions about her position on the team, but, once disclosed, it helped them reach a beneficial, mutual understanding of her performance.

Staff described awareness of possible distortion of data from various sources, particularly sleep (AT1, AT2, SCC1), though SCC1 indicates that he is confident in the data when athletes report 4-6 hours of sleep. Some staff also believe athletes deceive their tracking devices so it appears they are sleeping—e.g., by remaining completely still while watching a movie (SCC1) or by handing the tracker off to another person who is going to bed (SCC4). SCC4 assumes this to be the case when he observes signs of partying or a lack of sleep—e.g., alcohol on the breath, apparent fatigue—that are inconsistent with the sleep data reported by the device. In this way and by considering athletes'

personal lives and personalities, staff sometimes surmise—accurately or inaccurately—that athletes are distorting their data [47].

Both athlete distortion of data and staff knowledge of this practice is consistent with prior work on athlete self-report measures [47]. However, as staff rely on their instinct rather than evidence of distortion, there can be no certainty of accuracy for athlete self-reports. Without a different approach, the value of such reports is diminished [44, 47].

On the other hand, staff may put too much confidence in tracked data. While SCC1 and SCC4 described ways in which they are skeptical of tracked data, other staff may believe that just because data came from a sensor, they are accurate and reliable. This could result in over-training a fatigued athlete. Participants in our study also believe that staff sometimes use tracking data to make inferences that they do not actually support. This, in turn, can cause the athletes to focus on optimizing the data rather than the outcome. A8 describes how knowing her coach makes decisions based on heart rate data causes her to sometimes prioritize heart rate over rowing well:

> *Sometimes I wish the coach didn't know my heart rate because they will call you out . . . I would appreciate having the trust that I'm going to work my hardest to be in the necessary work zone without having somebody breathing down my neck because I guarantee you that I start to row crappy and my technique gets worse because I'm trying to get my heart rate up.*

While power asymmetries have always existed in high performance sports teams, tools that extend further into athletes' daily lives and that use automated tracking—even when intended to support both individual and team priorities—can magnify these asymmetries and disrupt teams' existing ways of managing them.

6.2 Discussion: Tracking breaks down routines and shows how extraction represents an important type of coordination artifact

6.2.1 Tracking breaks down existing team routines, threatening athlete agency. Nelson and Winter introduce the concept of *routine as truce* within organizations: to manage individuals' competing goals, *"routine operation is consistent with routinely occurring laxity, slippage, rule-breaking, defiance, and even sabotage"* [36]. This concept helps understand how team practices are changed by new tracking tools. When athletes communicate wellbeing data through self-report, they routinely distort that data in ways that help them save face, achieve their goals for training or play, or that help them avoid individual or team punishment. As our interviews indicate, staff are aware of and accept some of this distortion, and even account for it in their planning. In this routine, individual and team goals are balanced, and, in the words of Nelson and Winter:

> *There is a truce between the supervisor and those supervised at every level in the organizational hierarchy: the usual amount of work gets done, reprimands and compliments are delivered with the usual frequency, and no demands are presented for major modifications in the terms of the relationship.*

As described above, automated sensing limits athlete ability to distort their data and, thus, to defy rules while limiting the consequences. This breaks existing routines, reducing behavioral discretion. To the extent that this reduces injury risk, it may be beneficial. However, current staff practices around training, whether athletes play, and punishments were developed based on data that could be distorted, and so they may be overly punitive for this new data source. It also may increase staff power in ways that athletes do not experience as positive, and, as we also saw in interviews, athletes are already developing new practices to distort sensor data and regain some of their autonomy.

6.2.2 Extraction Artifacts: Considering the implications of power asymmetry in collaborations. We have shown and discussed situations where staff collect athlete data automatically or through self-report and where this collection is not by the athlete's choice and/or these data are not shared back to the athletes. Additionally, the borrowing artifacts created through these situations sit at the boundary between athletes and staff—the most significant power asymmetry we observed.

Lee defines borrowing artifacts by their procurement. Reflecting on the ways in which athlete data are collected—through devices with opaque uses that are opaque to athletes, through wellness surveys that must be complete or one's position on the team is in jeopardy—we suggest that "extraction" is a more precise characterization of the nature of the procurement described by participants than "borrowed." To reflect this nature of procurement and the power asymmetry around these artifacts, we propose a new kind of artifact that extends borrowing artifacts: ***extraction artifacts***.

To develop this extension to the boundary negotiating artifacts theory, we first discuss the key differences driving this distinction of *extraction artifacts*, then we develop a definition of *extraction artifacts* as a type of *borrowing artifact*.

The first important distinction between extraction and borrowing artifacts is in the procurement of the artifact. Where borrowing artifacts appear in our study, athletes cannot refuse the exchange of their data without risking their standing on the team. As athletes must give something to the staff, they may react by distorting the data before they share it (section 6.1). Their ability to shape the data they share is reduced when the artifact is procured automatically. The nature of data exchange in these situations is one of extraction, even if sharing ultimately leads to benefits for both the athlete and the team.

As a second distinction, Lee's definition of the procurement of borrowing artifacts relies on the borrower being in a "trusted position whereby he or she has access to [the borrowed] artifacts and can appropriate them... to further the goals of the project" [23]. Staff members are in a trusted position and use the artifact to further the goals of the team. However, while the athletes or their bodies provide the data in the artifacts, the staff who designed the survey or chose to use the device define what is collected from the athlete and how. In this way, the staff extract the data from athletes rather than borrow an artifact the athletes have already prepared.

Finally, in Lee's example of borrowing artifacts, the borrower is not in a position of power: they are waiting on others for the artifact to borrow. The act of borrowing is positioned as a reclamation of agency as they re-purpose shared artifacts so that they can carry on with their job. The artifacts in our data stand out because the positions of power are reversed. The staff, as borrowers or extractors, are in a position of power and use that position to extract the data needed for these artifacts—wellness survey results, reports on device data—hopefully, for the good of the team and the individual. Athletes are not in a position of power and cannot refuse the extraction without putting their relationships and standing on the team at risk; they can only distort the data the report.

Considering these distinctions, we define *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.** As we see for personal data about athletes, such extraction often transcends existing boundaries, reaching in to other contexts and even one's body.

As we see in our study, the use of tools that produce extraction artifacts, such as automatic tracking devices, can exacerbate the power asymmetries associated with collaborations and coordination. As described in section 6.2.1, 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. Further, when these data are not shared with athletes, they may not even know what about them is being communicated to others.

7 CONCLUSION

Our research contributes 1) An understanding of personal data-supported collaborations across four roles in collegiate sports teams; 2) The role of boundary negotiating artifacts—based, in part, on personal data—in supporting these collaborations; and, 3) A description of how the use of personal data in boundary negotiating artifacts can reinforce, extend, and sometimes challenge existing power asymmetries. In particular, our results show how both surveys and sensors that pull data about one individual or group into artifacts for use by others represent a type of coordinating artifact not previously described: extraction artifacts. Extraction artifacts challenge existing routines as individuals develop new ways to control or shape data to support their goals by reasserting their autonomy or power.

Though previous studies have demonstrated that the use of personal data in collaborations has the ability to support understanding and action planning and have emphasized the need for goal alignment (e.g, [10, 11]), our study emphasizes the importance of understanding power relationships that may be reinforced, undermined, or created when personal data are used in collaborations, especially in the design and adoption of tracking tools.

7.1 Extraction Artifacts as a Lens into Collaborations With Power Asymmetries

In considering how personal data are collected and used in collegiate sports teams, we found it helpful to define a new category of boundary negotiating artifact that better characterizes the power relationships we saw in our study: extraction artifacts. We believe that extraction artifacts can help CSCW researchers and designers understand power and surveillance issues associated with various types of personal data.

As seen in our study, even though the extraction artifacts used by the athletic teams were created to support coordination (e.g., adapting a training plan based on how well rested a student athletes was), they also became tools of surveillance. As with other types of surveillance [58], these tools then pushed student athletes to comply with staff or team expectations. Participating in tracking can help athletes achieve better individual and team performance and reduce risk of injury, while not participating could cause them to be excluded from games, practices, or even the team. As a result, they are strongly incentivized—if not compelled—to participate [44, 46]. However, athletes may not want or fully understand all of the consequences of surveillance, such as limited autonomy, lack of privacy, or psychological consequences of surveillance [59].

This shift from a coordinating or collaboration tool to a surveillance tool parallels other uses of personal data, e.g., in corporate or insurance wellness programs [10]. Even a simple social program intended to promote awareness (and thus a norm) of physical activity can take on attributes of surveillance [16]. It raises questions about at what point previously studied tools—such as those for sharing physical activity and nutrition data with one's health provider to access better expert advice and accountability[21]—become surveillance tools. Key distinctions may be in whether artifacts are *borrowed*, whether they are artifacts designed to *extract* information, and in the relative power of individuals in the collaboration.

We anticipate that this lens may be similarly helpful for studying other situations in which personal data are collected, including uses that already have more overt surveillance efforts. For example, workplaces monitor and surveil their employees to reduce costs or gain productivity [27, 30, 57]. Designers and researchers seeking to shift this relationship back from one of surveillance (e.g., who is productive?) to one of collaboration (e.g., how can we help you succeed at work?) may

consider how to shift from designing tools that are extraction artifacts into designing other types, such as borrowing or inclusion artifacts.

This is not to say that extraction artifacts are always problematic. When team staff design a survey or a data collection tool, they are able to ensure they get the information they need to support their decision making. Similarly, health-tracking researchers have recommended that clinicians contribute their medical expertise to the selection of tracking tools [10], again so that the resulting data support the decision-making process.

We also see nuanced value of extraction artifacts in other contexts. For example, delivery and long-haul truck drivers are tracked throughout their days using GPS [1, 43]. Such tracking can promote public safety (e.g., by ensuring rest requirements are met) and it can also be experienced as an oppressive form of scientific management. Additionally, the use of police body cameras to track interactions with the public [12] purposefully disrupts longstanding power asymmetries that have favored police.

7.2 Future Work

Research should further examine how the design and use of boundary negotiating artifacts reinforces or changes power asymmetries in collaborations. We hope that other researchers will apply our concept of extraction artifacts, refining the definition in the process. As a community of researchers and practitioners, we must develop new guidelines and design patterns for the creation and use of personal tracking tools. In contexts where the goal is collaboration, for example, design guidelines could emphasize the creation of inclusion artifacts that help bring together and balance multiple perspectives, over the use of extraction artifacts.

In addition, we hope that designers of personal informatics tools and those responsible for their adoption will find the examples we present from collegiate athletics informative, and boundary negotiating artifacts useful in considering what types of tools they design and adopt.

7.3 Concluding Remarks

Through the example of collegiate sports teams, our research shows that the collection and use of personal data has the potential to support collaborations that further individual and organizational goals. However, it can also result in decreased individual agency and surveillance. Careful consideration of design choices for the collection, use, and return of personal data are necessary for promoting individual agency and supporting individual lived experiences. Though we conducted our study in the context of US collegiate athletic organizations, we expect that many of the issues we identified around the collection and use of personal data apply more broadly, including in other athletic organizations as they too adopt tracking technologies, in healthcare settings, and in the workplace.

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REFERENCES

[1] Yorghos Apostolopoulos, Michael Lemke, and Sevil Sönmez. 2014. Risks Endemic to Long-Haul Trucking in North America: Strategies to Protect and Promote Driver Well-Being. *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy* 24, 1 (2014), 57–81. DOI: http://dx.doi.org/10.2190/ns.24.1.c

[2] Athos. 2017. Athos Training System. (2017). https://www.liveathos.com/

[3] Hugh Beyer and Karen Holtzblatt. 1997. *Contextual design: defining customer-centered systems.* Elsevier, Amsterdam, Netherlands. 472 pages.

[4] CBS Boston. 2016. Top 10 Gutsiest In-Game Performances By Injured Athletes. https://boston.cbslocal.com/2016/01/11/top-10-gutsiest-in-game-performances-by-injured-athletes/. (Jan. 2016). Accessed: 2019-9-24.

[5] Pitre C Bourdon, Marco Cardinale, Andrew Murray, Paul Gastin, Michael Kellmann, Matthew C Varley, Tim J Gabbett, Aaron J Coutts, Darren J Burgess, Warren Gregson, and N Timothy Cable. 2017. Monitoring Athlete Training Loads: Consensus Statement. *International journal of sports physiology and performance* 12, Suppl 2 (apr 2017), S2161–S2170. DOI: http://dx.doi.org/10.1123/IJSPP.2017-0208

[6] Kelly Caine. 2016. Local Standards for Sample Size at CHI. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems - CHI '16*. ACM, New York, NY, USA, 981–992. DOI: http://dx.doi.org/10.1145/2858036.2858498

[7] Marco Cardinale and M.C. Matthew C Varley. 2017. Wearable Training-Monitoring Technology : Applications , Challenges , and Opportunities. *International Journal of Sports Physiology and Performance* 12 (2017), 55–63. DOI: http://dx.doi.org/10.1123/ijspp.2016-0423

[8] Catapult. 2019. Catapult Sports | We create technology to help athletes and teams perform to their true potential. (2019). https://www.catapultsports.com/

[9] Kathy Charmaz. 2006. *Constructing grounded theory: A practical guide through qualitative analysis.* Sage, Thousand Oaks, CA, USA.

[10] Chia-fang Chung, Kristin Dew, Allison M Cole, Jasmine Zia, James A Fogarty, Julie A Kientz, and Sean A Munson. 2016. Boundary Negotiating Artifacts in Personal Informatics: Patient-Provider Collaboration with Patient-Generated Data. In *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing - CSCW '16*. ACM, New York, NY, USA, 768–784. DOI: http://dx.doi.org/10.1145/2818048.2819926

[11] Chia-Fang Chung, Qiaosi Wang, Jessica Schroeder, Allison Cole, Jasmine Zia, James Fogarty, and Sean A. Munson. 2019. Identifying and Planning for Individualized Change: Patient-Provider Collaboration Using Lightweight Food Diaries in Healthy Eating and Irritable Bowel Syndrome. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 3, 1 (2019), 1–27. DOI: http://dx.doi.org/10.1145/3314394

[12] Fanny Coudert, Denis Butin, and Daniel Le Métayer. 2015. Body-worn cameras for police accountability: Opportunities and risks. *Computer Law and Security Review* 31, 6 (2015), 749–762. DOI: http://dx.doi.org/10.1016/j.clsr.2015.09.002

[13] Daniel A. Epstein, Bradley H. Jacobson, Elizabeth Bales, David W. McDonald, and Sean A. Munson. 2015. From "nobody cares" to "way to go!": A Design Framework for Social Sharing in Personal Informatics. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing - CSCW '15*. ACM Press, New York, NY, USA, 1622–1636. DOI: http://dx.doi.org/10.1145/2675133.2675135

[14] FitBit. 2007. Fitbit Official Site for Activity Trackers & More. (2007). https://www.fitbit.com/

[15] Erving Goffman. 1959. *The presentation of self in everyday life.* Anchor Books, New York, NY, USA.

[16] Nanna Gorm and Irina Shklovski. 2016. Steps, choices and moral accounting: observations from a step-counting campaign in the workplace. In *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing*. ACM, New York, NY, USA, 148–159.

[17] Sofia Jowett and Ian Cockerill. 2002. Incompatibility in the coach-athlete relationship. In *Solutions in Sport Psychology*, Ian Cockerill (Ed.). Thomson, London, United Kingdom, Chapter 2, 16–31.

[18] Sophia Jowett and David Lavallee. 2007. *Social Psychology in Sport.* Human Kinetics, Champaign, IL, USA.

[19] Yoojung Kim, Eunyoung Heo, Hyunjeong Lee, Sookyoung Ji, Jueun Choi, Jeong-whun Kim, Joongseek Lee, and Sooyoung Yoo. 2017. Prescribing 10,000 Steps Like Aspirin. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI '17*. ACM Press, New York, New York, USA, 5787–5799. DOI: http://dx.doi.org/10.1145/3025453.3025570

[20] Yoojung Kim, Sookyoung Ji, Hyunjeong Lee, Jeong-Whun Kim, Sooyoung Yoo, and Joongseek Lee. 2016. "My Doctor is Keeping an Eye on Me!": Exploring the Clinical Applicability of a Mobile Food Logger. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*. ACM, New York, NY, USA, 5620–5631. DOI: http://dx.doi.org/10.1145/2858036.2858145

[21] Yoojung Kim, Sookyoung Ji, Hyunjeong Lee, Jeong-Whun Kim, Sooyoung Yoo, and Joongseek Lee. 2016. My doctor is keeping an eye on me!: Exploring the clinical applicability of a mobile food logger. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 5620–5631.

[22] Francisco Kiss, Paweł W. Wozniak, Felix Scheerer, Julia Dominiak, Andrzej Romanowski, and Albrecht Schmidt. 2019. Clairbuoyance: Improviing Directional Perception for Swimmers. In *Proceedings of the 2019 CHI Conference on Human*

Factors in Computing Systems - CHI '19. ACM Press, New York, New York, USA, 1–12. DOI: http://dx.doi.org/10.1145/3290605.3300467

[23] Charlotte P. Lee. 2007. Boundary negotiating artifacts: Unbinding the routine of boundary objects and embracing chaos in collaborative work. *Computer Supported Cooperative Work* 16, 3 (2007), 307–339. DOI: http://dx.doi.org/10.1007/s10606-007-9044-5

[24] James J. Lin, Lena Mamykina, Silvia Lindtner, Gregory Delajoux, and Henry B. Strub. 2006. Fish'n'Steps: Encouraging physical activity with an interactive computer game. In *International conference on ubiquitous computing (UbiComp '06)*. Springer, Berlin, Germany, 261–278.

[25] Leilani Madrigal, Jamie Robbins, Diane L. Gill, and Katherine Wurst. 2015. A Pilot Study Investigating the Reasons for Playing Through Pain and Injury: Emerging Themes in Men's and Women's Collegiate Rugby. *Sport Psychologist* 29, 4 (2015), 310–318. DOI: http://dx.doi.org/10.1123/tsp.2014-0139

[26] Geneviève A Mageau and Robert J Vallerand. 2003. The coach-athlete relationship: a motivational model. *Journal of Sports Sciences* 21, 11 (nov 2003), 883–904. DOI: http://dx.doi.org/10.1080/0264041031000140374

[27] Akhil Mathur, Marc Van den Broeck, Geert Vanderhulst, Afra Mashhadi, and Fahim Kawsar. 2015. Tiny Habits in the Giant Enterprise: Understanding the Dynamics of a Quantified Workplace. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '15)*. ACM, New York, NY, USA, 577–588. DOI: http://dx.doi.org/10.1145/2750858.2807528

[28] Matthew Mauriello, Michael Gubbels, and Jon E Froehlich. 2014. Social Fabric Fitness: The Design and Evaluation of Wearable E-Textile Displays to Support Group Running. In *CHI 2014, One of a CHInd*. ACM, New York, NY, USA, 2833–2842. DOI: http://dx.doi.org/10.1145/2556288.2557299

[29] Medtronic. 2019. Zephyr Performance Systems: Sports. (2019). https://www.zephyranywhere.com/users/sports

[30] Andre N. Meyer, Gail C. Murphy, Thomas Zimmermann, and Thomas Fritz. 2017. Design Recommendations for Self-Monitoring in the Workplace: Studies in Software Development. *Proc. ACM Hum.-Comput. Interact.* 1, CSCW, Article 79 (Dec. 2017), 24 pages. DOI: http://dx.doi.org/10.1145/3134714

[31] Andrew Miller, Erika Poole, Yan Xu, Elsa Eiriksdottir, Daniel Kestranek, Richard Catrambone, and Elizabeth Mynatt. 2012. The work of play: supporting a pervasive health behavior change intervention for us middle school students. In *Proceedings of the ACM 2012 conference on computer supported cooperative work*. ACM, New York, NY, USA, 897–900. DOI: http://dx.doi.org/10.1145/2145204.2145337

[32] Zebra Motionworks. 2019. Zebra Motionworks Sport: Real-time Player Tracking. (2019). https://www.zebra.com/us/en/solutions/rtls/sports-player-tracking.html

[33] Elizabeth L Murnane, Tara G Walker, Beck Tench, Stephen Voida, and Jaime Snyder. 2018. Personal Informatics in Interpersonal Contexts. *Proceedings of the ACM on Human-Computer Interaction* 2, CSCW (nov 2018), 1–27. DOI: http://dx.doi.org/10.1145/3274396

[34] National Athletic Trainers' Association's Intercollegiate Council for Sports Medicine. 2019. Only Half of Collegiate-Level Sports Programs Follow Medical Model of Care for Student Athletes, Survey Finds. https://www.nata.org/press-release/062619/only-half-collegiate-level-sports-programs-follow-medical-model-care-student. (June 2019). Accessed: 2019-10-1.

[35] National Collegiate Athletic Association (NCAA). 2015. NCAA.org - The Official Site of the NCAA. (2015). http://www.ncaa.org/

[36] Richard R. Nelson and Sidney G. Winter. 1982. *An evolutionary theory of economic change*. Belknap Press of Harvard University Press, Cambridge, MA, USA. http://inctpped.ie.ufrj.br/spiderweb/pdf_2/Dosi_1_An_evolutionary-theory-of_economic_change..pdf

[37] Kim Oakes, Katie Siek, and Haley MacLeod. 2015. MuscleMemory: Identifying the Scope of Wearable Technology in High Intensity Exercise Communities. In *Proceedings of the 9th International Conference on Pervasive Computing Technologies for Healthcare*. IEEE, Piscataway, NJ, USA, 193–200. DOI: http://dx.doi.org/10.4108/icst.pervasivehealth.2015.259162

[38] Alkisti Olympiou, Sophia Jowett, and Joan L Duda. 2016. The Psychological Interface between the Coach-Created Motivational Climate and the Coach-Athlete Relationship in Team Sports. *The Sport Psychologist* 22, 4 (2016), 423–438. DOI: http://dx.doi.org/10.1123/tsp.22.4.423

[39] Laura R Pina, Sang-Wha Sien, Teresa Ward, Jason C Yip, Sean A Munson, James Fogarty, and Julie A Kientz. 2017. From Personal Informatics to Family Informatics. In *Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing - CSCW '17*. ACM Press, New York, NY, USA, 2300–2315. DOI: http://dx.doi.org/10.1145/2998181.2998362

[40] Artur Poczwardowski, Brooke Lamphere, Kirsten Allen, Rendy Marican, and Peter Haberl. 2019. The 5C's Model of Successful Partnerships in Elite Beach Volleyball Dyads. *Journal of Applied Sport Psychology* 31, 1 (2019), 1–19. DOI: http://dx.doi.org/10.1080/10413200.2019.1573205

[41] Amon Rapp and Lia Tirabeni. 2018. Personal Informatics for Sport. *ACM Transactions on Computer-Human Interaction* 25, 3 (jun 2018), 1–30. DOI: http://dx.doi.org/10.1145/3196829

[42] Corinne Reid, Evan Stewart, and Greg Thorne. 2004. Multidisciplinary Sport Science Teams in Elite Sport: Comprehensive Servicing or Conflict and Confusion? *The Sport Psychologist* 18, 2 (2004), 204–217. DOI: http://dx.doi.org/10.1123/tsp.18.2.204

[43] Matthias Roetting, Yueng Hsiang Huang, Jamie R. McDevitt, and David Melton. 2003. When technology tells you how you drive - Truck drivers' attitudes towards feedback by technology. *Transportation Research Part F: Traffic Psychology and Behaviour* 6, 4 (2003), 275–287. DOI: http://dx.doi.org/10.1016/j.trf.2003.09.001

[44] Anna Saw, Luana Main, Paul Gastin, and Anna Saw. 2015. Monitoring athletes through self- report: Factors influencing implementation. *Journal of Sports Science & Medicine* 14, 1 (2015), 137–146. DOI: http://dx.doi.org/10.1519/JSC.0000000000000499

[45] Anna Saw, Luana Main, Sam Robertson, and Paul Gastin. 2017. Athlete Self-Report Measure Use and Associated Psychological Alterations. *Sports* 5, 3 (2017), 54. DOI: http://dx.doi.org/10.3390/sports5030054

[46] Anna E Saw, Luana C Main, and Paul B Gastin. 2015. Impact of Sport Context and Support on the Use of a Self-Report Measure for Athlete Monitoring. *Journal of Sports Science and Medicine* 14 (2015), 732–739. http://www.jssm.org

[47] Anna E. Saw, Luana C. Main, and Paul B. Gastin. 2015. Role of a self-report measure in athlete preparation. *Journal of Strength and Conditioning Research* 29, 3 (2015), 685–691. DOI: http://dx.doi.org/10.1519/JSC.0000000000000698

[48] Jessica Schroeder, Chia-Fang Chung, Daniel A Epstein, Ravi Karkar, Adele Parsons, Natalia Murinova, James Fogarty, and Sean A Munson. 2018. Examining self-tracking by people with migraine: goals, needs, and opportunities in a chronic health condition. In *Proceedings of the 2018 on Designing Interactive Systems Conference 2018*. ACM, New York, NY, USA, 135–148.

[49] Jessica Schroeder, Jane Hoffswell, Chia-Fang Chung, James Fogarty, Sean Munson, and Jasmine Zia. 2017. Supporting Patient-Provider Collaboration to Identify Individual Triggers using Food and Symptom Journals. In *Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing - CSCW '17*. ACM Press, New York, NY, USA, 1726–1739. DOI: http://dx.doi.org/10.1145/2998181.2998276

[50] Susan Leigh Star and James R. Griesemer. 1989. Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social Studies of Science* 19, 3 (aug 1989), 387–420. DOI: http://dx.doi.org/10.1177/030631289019003001

[51] Jakob Tholander and Stina Nylander. 2015. Snot, Sweat, Pain, Mud, and Snow. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI '15*. ACM Press, New York, NY, USA, 2913–2922. DOI: http://dx.doi.org/10.1145/2702123.2702482

[52] Polar USA. 2019. Team Sports | Win more games with wearable technology for sport teams | Polar USA. (2019). https://www.polar.com/us-en/b2b_products/team-sports

[53] Svenja Wachsmuth, Sophia Jowett, and Chris G. Harwood. 2016. Conflict among athletes and their coaches: what is the theory and research so far? *International Review of Sport and Exercise Psychology* 10, 1 (jan 2016), 84–107. DOI: http://dx.doi.org/10.1080/1750984X.2016.1184698

[54] Svenja Wachsmuth, Sophia Jowett, and Chris G Harwood. 2018. Managing Conflict in CoachâĂŤAthlete Relationships. *Sport, Exercise, and Performance Psychology* 7, 4 (2018), 371–391. DOI: http://dx.doi.org/10.1037/spy0000129.supp

[55] Sherry K. Watt and James L. Moore. 2004. Who Are Student Athletes? *New Directions for Student Services* 2001, 93 (2004), 7–18. DOI: http://dx.doi.org/10.1002/ss.1

[56] Paweł W. Woźniak, Anton Fedosov, Eleonora Mencarini, Kristina Knaving, and Jakob Tholander. 2017. Soil, Rock and Snow: on Designing for Information Sharing in Outdoor Sports. *Interactions* 22, 2 (2017), 611–623. DOI: http://dx.doi.org/10.1515/ICOM-2017-0017

[57] Wenbing Zhao, Roanna Lun, Connor Gordon, Abou-Bakar M Fofana, Deborah D Espy, M Ann Reinthal, Beth Ekelman, Glenn D Goodman, Joan E Niederriter, and Xiong Luo. 2016. A human-centered activity tracking system: Toward a healthier workplace. *IEEE Transactions on Human-Machine Systems* 47, 3 (2016), 343–355.

[58] Shoshana Zuboff. 1988. *In the age of the smart machine: The future of work and power*. Vol. 186. Basic Books, New York, NY, USA.

[59] David Zweig. 2005. Beyond Privacy and Fairness Concerns: Examining Psychological Boundary Violations as a Consequence of Electronic Performance Monitoring. In *Electronic Monitoring in the Workplace: Controversies and Solutions*. IGI Global, 101–122.

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