Personal Informatics Needs for Amateur Athletic Coaching and Self-Coaching

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ABSTRACT

Personal informatics applications and visualizations are increasingly available for amateur endurance athletes to record and monitor their performance and training. This information can be valuable for self-coached athletes or coaches of amateur athletes who tailor training programs based on this data. Despite this, it is not clear if the information provided by such tools map to the real needs of the amateur athletic community. To address this, we conducted in-depth interviews with eight amateur athletic coaches. Our results show that athlete-specific contextual factors such as injuries, illness, sleep, stress, and mood can be important to track and monitor in relation to performance-based metrics as they allow coaches to tailor training programs. Yet most commercially-available tools do not allow athletes to easily capture or analyse this information in relation to one another. It can also be challenging to share this information between athletes and coaches. This suggests that personal informatics applications could better serve the endurance athletic community by broadening the available data that can be recorded, shared, displayed, and analysed by self-coached athletes or coaches.

Keywords: Athletes, personal informatics, sports, physical activity, self-improvement, coaching, reflection, awareness.

Index Terms: H.5.2 [Information Interfaces and Presentation]: User Interfaces–User Centered Design; H.5.3 [Group and Organization Interfaces]: Collaborative computing

1 INTRODUCTION

Recent advancements in technology have led to an increase in the adoption of personal informatics systems: a class of systems that "help people collect personally relevant information for the purposes of self-reflection and gaining self-knowledge" [10]. One area this has occurred is in the endurance athletic community by amateur athletes—athletes that train and compete at the amateur level (primarily without pay) who are either coached by an experienced person or are self-coached (e.g., high school athletes, college or varsity athletes). Endurance athletics refers to sports that require an athlete to perform over an extended distance or time period [18].

In this area, we see that amateur swimmers, cyclists, and runners often use devices that couple Global Poisoning Systems (GPS) with other technologies such as heart rate monitors, power meters, accelerometers, and cadence sensors [15]. Advancements in web-based technologies and visualizations provide these athletes with training resources such as logs and online coaches [15][19]. For example, GPS-enabled watches such as the Garmin 910 use ANT+ technology to capture data from biofeedback devices and allow users to record information for swimming, running and cycling workouts. This information can be uploaded to numerous sport-specific personal informatics web tools, such as Strava or MapMyRide, which allow users to access and view the workout data. Athletes can then analyse their workouts after the training is complete.

As the number of amateur athletes using these smart technologies increases, the opportunity for coaches to analyse or monitor an athlete's performance and adjust the athlete's training program increases accordingly. Thus, even though personal informatics systems are designed for individuals, the data from them may be relevant for other people, such as athletic coaches. Through introspection[1], we feel that although an increasing number of amateur athletes are using these devices, many of them do not share this data with coaches, as they are either self-coached or they feel the information provided by these devices may not necessarily be helpful to an athletic coach.

For this reason, this paper examines the increasing role that technology and personal informatics plays in amateur endurance sport planning, training, and monitoring. We were interested in understanding how well current athletic performance tracking systems mapped to the real needs of amateur athletes and coaches. Specifically, the goal of the research was twofold. First, we wanted to assess if the information provided in personal informatics systems mapped to the information that coaches desire to know about their athletes in order to help tailor training programs. Second, for self-coached amateur athletes, we wanted to understand what information such systems could provide them in order to improve their self-coaching methods.

To address these goals, we conducted in-depth interviews with eight amateur athletic coaches from either a high school or university athletic program. Our results show that while performance metrics are important, additional athlete-specific contextual information such as perceived exertion rate, injuries and illnesses, sleep and stress, and mood can all be valuable for coaches to know about. Yet this information can be challenging to record and analyse. This suggests that personal informatics applications could broaden the scope of the information they collect and present to users such that amateur athletes and coaches can better understand the effect of athlete-specific contextual factors on their training.

The remainder of our paper unfolds as follows. First, we outline related work on personal informatics, physical activity, and athletic training. Second, we describe our interview study methodology. Third, we report our results and then outline implications for the design of personal informatics systems for amateur athletes and coaches.

2 RELATED WORK

2.1.1 Personal Informatics Systems

Personal informatics is a growing area of research in the human-computer interaction community with a variety of personal informatics applications being created for different purposes. For example, MyLifeBits collects and links together all of one's activities and their associated documents when people are using their computers [6]. The goal is to provide a "surrogate memory" for people [6]. SenseCam, a wearable camera that hangs from a

[1] The first author has been an amateur athlete for several years.

user's neck and captures images throughout one's day, allows people to collect information about their activities for later reflection [9]. Mycrocosm allows users to record and view "personal statistics" about themselves including things like food eaten, sleep times, or clothing choices [2].

More specifically focused on our topic of physical activity and athletics, we see several examples of systems designed to support self-reflection. For example, Lin et al. [15] designed Fish'n'Steps which displays an animated character in a fish tank based on a user's activity levels as recorded by a pedometer. As activity levels increase, the size of the fish grows. A study showed that the feedback provided by the system encouraged users to change their physical activity routines [15]. UbiFit Garden is a mobile application that displays a growing garden based on a user's activity as sensed by a collection of environmental and activity sensors (e.g., humidity, barometer, accelerometer). Study results point to challenges in using on-body sensors for detecting physical activity levels and suggest a combination of sensed-activity recording and manual entries by users [5]. Shakra tracks and shares user activity levels (e.g., stationary, walking, driving) using satellite signals on a mobile phone [1]. Users reported that they enjoyed the application and it provided them with an additional awareness of their activity levels that they normally would not have had [1].

2.1.2 Models and Studies of Personal Informatics

We also see research that focuses on theoretical contributions for understanding personal informatics and the design of applications to support it. The Stage Based Model of personal informatics systems provides a framework for developing, evaluating, describing, and comparing personal informatics systems [10]. The model was derived from responses of individuals about their collection of personal information related to financial statements, computer activity (e.g., email, web browsing history), bills, exercise, and work activities [10]. The model consists of five stages—preparation, collection, integration, reflection, and action—and outlines the barriers, or potential 'pain points' for personal data collection and analysis at each of these stages [10]. This includes, for example, knowing what information to collect (preparation stage), not having a good tool for collection (collection stage), synthesizing an understanding across multiple data sources (integration stage), a lack of time (reflection stage), and not knowing what to do based on data (action stage) [10]. One of the goals of our research is to further understand how these stages in personal informatics systems can better map to the needs of coaches and athletes.

Building on the above research, a study by Li et al. [13] developed an understanding of the types of questions that users had in relation to their personal informatics, and further interpreted how these users were answering those questions through the use of the current personal informatics technologies. Questions focused on understanding a user's current status, looking at trends over time, comparing one's status to goals, looking for discrepancies, understanding the context around data, and knowing what factors affect their status [13]. The authors also explain that there are two types of phases in the reflection stage, discovery and maintenance, which affect the types of questions people asked [13]. In the maintenance stage, users have developed program-level goals which act as a reference point for users to compare and track their progress, while in the discovery stage users used the data to try to create a baseline in which to determine areas to take action on or determine which specific actions to take in order to change a behaviour [13].

Li et al. [14] investigated the affects of contextual information in relation to physical activity. Through different methods of data gathering, activity and contextual information, the study reveals that users are more likely to use and continue to use a personal informatics system for a long period of time if the data collection is integrated or semi-automated [14]. However, the act of manually recorded information made participants more aware of their data and its effects on their performance [14]. The study also suggests that other contextual information such as calendars, mood, and weather can provide insight to users when reflecting on his/her activity [14]. Lastly, the study explains the need to provide ways for users to act upon his or her data and newfound knowledge. They describe that many personal informatics systems have yet to expand past the ability to track the amount of physical activity a particular user has completed [14]. This suggests that there are potential use cases for a system that draws conclusions from a user's data and gives the user the knowledge and tools to explore this data more intuitively.

2.1.3 Endurance Athletic Training

Training is vital to endurance athletics and most athletes train their cardiovascular system multiple times per week to increase performance abilities [18]. Performance levels depend on three main factors: maximal aerobic power (roughly defined as the body's ability to use oxygen), lactate threshold (the point at which lactic acid accumulates in the blood stream and needs to be removed), and economy (the amount of energy expended to produce a particular speed) [17]. Training tries to increase all three of these.

A typical goal for endurance athletic training programs is to find a level of workout that pushes the athlete to a maximal performance state without inducing overtraining [10][18]. Training is performed by first overloading the body and pushing it to do more than it normally would. These periods of overloading are followed by a recovery period where an athlete rests and regenerates herself [18]. Overtime, the body's performance abilities increase because of the overloading [18]. The challenge is figuring how much the body can handle before overtraining occurs. If overtraining occurs, an athlete can develop psychological symptoms, such as depressed moods, loss of appetite, difficulties concentrating, etc., or physiological effects, such as poorer performance, increased respiration, or elevated heart rates during further training [18].

In order to monitor training, sports medicine literature suggests monitoring five psychological variables: including one's general well-being, quality of sleep, success, social stress, and fitness or injury [11]. This can be done through conversation with athletes or by using quantitative questionnaires that assess each component [11][18]. Coaches can also have athletes assess themselves using the 'rating of perceived exertion,' originally a numerical scale ranging from 6 (no exertion at all) to 20 (maximal exertion) [3]. We also know that additional factors also affect an athlete's training. This includes one's diet [17][20], water and electrolyte balance, the intake of vitamins and minerals [17], as well as sleep, circadian rhythm, and travel fatigue [20].

3 STUDY METHOD

The study that we conducted was aimed at learning what types of athlete-related information endurance athletic coaches keep record of, what record-keeping systems they use (if any), how athletes inform them of training-relevant information, and how these records are used to improve an athlete's training. The study findings were determined through data analysis of semi-structured

Table 1: Participant demographics and sport classification.

	Gender	Age Range	Sport / Experience	Background	Athletes Coached
P1	Female	35-45	Track & Cross Country	Former Athlete	Team: 5-6
P2	Female	55+	Track & Cross Country	Former Elite Level Athlete	Team: 12-24
P3	Male	35-45	Triathalon	Athlete & Kinesiologist	Team: 5-10
P4	Male	25-35	Track & Cross Country	Former Athlete	Team: 14-30
P5	Male	55+	Track & Cross Country	Former Elite Level Athlete	Team: 14-30
P6	Male	25-35	Cycling	Athlete	Individuals: 4
P7	Male	35-45	Cycling	Athlete & Kinesiologist	Individuals: 6
P8	Male	35-45	Track & Cross Country	Former Elite Level Athlete	Team: 2

interviews with coaches. The participants, interview protocol, and methods of data analysis are described in the following sections.

3.1 Participants

Through convenience sampling, we recruited eight participants (two female) from a major metropolitan city in Canada who had experience coaching amateur endurance. Five participants had coached track and cross country running teams, two participants had coached individual road cyclists, and one of the participants coached a group of triathletes (Table 1). While all of the participants tracked some type of athlete-related data for at least a small number of their athletes, only three participants had used athletic web systems and biofeedback devices to do so. Two participants used online systems, such as Google Docs or Training Peaks, as platforms for communicating and recording workout data, and the rest of the participants recorded data either through pen and paper, or through a combination of pen and paper and Microsoft Excel. The participants using web and biofeedback devices gave us insight into how these systems are currently being used, and highlighted the areas in which these systems were not meeting their needs as coaches. The participants not using these technologies allowed us to understand the specific elements or factors that coaches wanted to track in order to evaluate performance and the monitoring of their athletes. All of the participants were able to provide us with insight into how a competitive season is planned and training programs are created, thus allowing us to develop an understanding of what a personal informatics system could provide for a self-coached athlete.

3.2 Interview Method

We conducted in-depth semi-structured interviews that lasted roughly sixty minutes in length. Interview questions were organized into four different sections.

1. Background: The first set of questions was aimed at understanding the coach persona and how it differed between each of the sports. In this section we asked coaches questions such as, "What sport(s) are you currently coaching or have coached in the past?" and "How and why did you get involved with coaching?"

2. Coach-Athlete Interactions: The second interview section focused on examining the interaction and communication methods between the coach and the athlete(s). We also wanted to learn about the types of specific information that coaches collected in relation to a workout or an athlete, and how that information was being monitored or analysed. Examples from this section included questions such as, "Do you actively monitor athletes improvements or declines in performance?" and "Do you keep records of athlete performance from practices or events?" Each of these questions went further in-depth by asking coaches more details such as, "How are these improvements or declines monitored?", "What type of measures are being monitored to asses the athlete's performance?" and "What are your main reasons for documenting these performances?"

3. Coaching Methodology and Planning: The third set of questions regarded workout and program planning. The goal of this section was to evaluate if any of the coach's processes could be enhanced with current technological systems, and if these processes would be useful if provided to a self-trained athlete. Example questions included "Do you use any athlete data to structure training programs and schedules?" (e.g., workouts can be structured so that an athlete performs in a certain heart rate zone, or at a specific wattage output) and "Do you follow any type of periodization while planning workouts or practices?" (e.g., adequate rest weeks, peaking for specific games, events or races).

4. Technology and Personal Informatics Systems: The last major set of questions was aimed at evaluating how many of the coached athletes used any of the current systems or biofeedback technologies, and if any of these devices were used at any point of the training process. This section also allowed participants to evaluate some of the current systems, and provide us with insight into what parts of these systems would be useful for coaches.

For example, in this section we showed coaches a sample workout from three of the most commonly used personal informatics athletic applications: Garmin Connect, Strava, and Nike+. We asked them to imagine they were the athlete's coach and analyse the given workouts. After the coaches had some time to look over the workouts, we asked them related questions such as, "Can you describe what each of these sections are and how they might be beneficial, or not useful to you as the coach of this athlete?" and "From a coach's perceptive, is there anything on this page that is missing that would be beneficial to see in order to monitor this athlete's progress or further discover trends in this athlete's workout behaviors? If so, please explain." Finally we wrapped up the interview by asking participants about their experience using these online training systems. For participants who had no experience, we asked if they would ever consider implementing such a system in their current training process.

3.3 Data Analysis

All of the interviews were recorded through handwritten notes and interpreted through thematic analysis [1][8]. Once all the interviews were completed, we examined each participant's results to familiarize ourselves with the data. Next, we highlighted and coded any of the main areas or reoccurring topics that were recurring themes. We then reviewed and iterated on these until we established what we thought were the main findings. Through this analysis, we were able to identify several themes that form the main discussion in our results and subsequent sections. Throughout the results, we refer to participants by their participant number (see Table 1).

4 RESULTS

The results of our study revealed several main themes that correspond to the tracking or recording of athlete-related information and methodology that contributes to the development of seasonal training programs. The following sub-sections described each of these themes in detail.

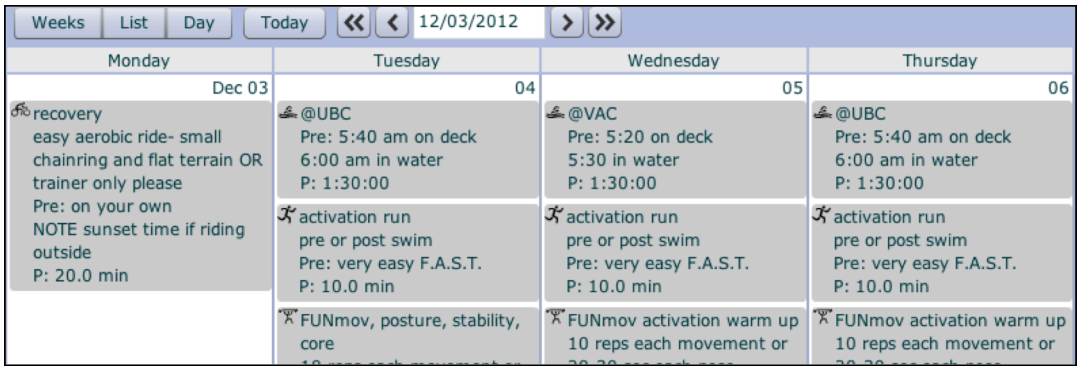

Figure 1: A coach's records of athlete workouts using the Training Peaks online system.

4.1 Contextual Information

Tracking contextual information in relation to training or a workout result allows for greater depth of analysis and provides an opportunity for coaches or athletes to answer any training or performance related questions surrounding the data. Most personal informatics applications can track general contextual factors such as weather, temperature, and time. While these may be important for analyzing a particular workout and the effect of the contextual factors on it, nearly all coaches in our study were most concerned with tracking contextual factors that were determined by and related to an *individual athlete*, rather than the *environment*. These athlete-specific factors were seen as being beneficial for analyzing individual workout results and also, on a larger scale, to evaluate training programs, prevent injury, and maximize athlete potential.

Throughout the interviews, coaches identified four main areas of athlete-specific information that they felt was important to know and understand in order to evaluate, adapt, and improve an athlete's training and performance: rate of perceived exertion, injuries and illnesses, sleep and stress, and mood. These details were often evaluated by observing a particular athlete or were communicated from the affected athlete. Generally this took place before and after workouts or periodically throughout the week, as athletes reported results from workouts where the coach was not present. We elaborate on each of these contextual factors next.

4.1.1 Rate of Perceived Exertion

Participants told us that one of the most common factors that a coach will evaluate is an athlete's Rate of Perceived Exertion (RPE). RPE is described by P7 as usually being a "*number or percentage that represents how an athlete felt during the workout*" (P7). This contextual factor can be used easily in comparison with workout data, such as distance and time, to track an athlete's performance over time. For instance, P8 describes that he can user RPE to predict when an athlete is starting to do too much training or becoming overtrained. If one of his athlete's communicates a high RPE for a workout that would usually coincide with a low RPE, than he can quickly see that this particular athlete was working too hard, and thus may be at risk of overtraining. Additionally, RPE can be used to quickly monitor a large number of athletes. P7 gets his athletes to record their RPE alongside any workout-related data. He then monitors the values over a weekly or monthly period to discover if any athletes have been predominately overworked or have a consistently high RPE. For example, Figure 1 shows data from a coach who has recorded the difficulty of daily workouts for his athlete. Comments such as "easy" (Dec 3) or "very easy" (Dec 4) are seen in several days.

Though RPE can help coaches further analyse workout data, only two of the eight participants explicitly recorded this data. Four of the other participants explained they will often verbally communicate with an athlete after the workout is completed to determine RPE or understand how the athlete felt during the training. These coaches chose not to record these factors as they either had a small number of athletes, and usually remembered such reactions, or had too many athletes and felt the extra transcription was too tedious.

4.1.2 Injuries & Illnesses

Seven of eight coaches explained that when an athlete is starting to feel any signs of an injury or illness, s/he will communicate the issue to the coach and usually describe the pain or symptoms on a severity scale. At this point, coaches try to record the information and are mainly concerned with the seriousness of the problem. Figure 2 shows the documentation of sickness (in the "Comments" column) by one athlete in a Google Doc that is shared with her coach. Four participants explained how it was most important to understand what the injury or illness was to determine how long the athlete would need to rest. This way they could alter any current or future workouts accordingly to help the athlete recover while still maintaining their fitness. This process often involves further communication with sports doctors and physiotherapists as the athlete and coach do not have the specific knowledge to diagnose the problem.

For example, P1 explained how a proper evaluation of an athlete's symptoms could have prevented an injury that forced the athlete to end his season early. The athlete had described having no real pain during training with the exception of a dull ache in the shin that lasted for several hours after completing each workout. Due to the athlete's lack of pain during exercise, and his eagerness to continue training, the coach allowed the athlete to continue to practice and recommended treating the issue with ice. After completing several more weeks of training, the athlete's pain elevated and he was unable to complete any workouts. A bone scan later revealed that the injury was a stress fracture that would force the athlete to stop running for at least one month. The participant told us that if a physiotherapist had evaluated the symptoms early on, then it might have been possible to prevent injury from progressing. With proper treatment and rest, the athlete would have been able to complete the season.

Four of the interviewed coaches described the primary challenge with injury and sickness as prevention. One coach related the issue to lack of communication:

"*The problem is that they let the injury get bad before they tell me about it, or they don't tell me at all and I find out while at practice… if they communicate these injuries, even when they are very minor, I can alter their practice, or send them to the pool.*

Date	Workout	Interval Time	Weekly Mileage	Comments
Sat. 2, 2011	800, 4x800	2.19.08, 2.23		Sick :(had bad cold- sore throat and bad cough in lungs
Sun. 3, 2011				
Tues. 5, 2011	2x800 4x400 3' 6'	2:42, 2:45, 75, 76		Still sick- lungs were really tight during workout and couldnt breathe without coughing
Tues. 12, 2011	2x400 4x200 3' 6'			Have final exam @ 3:30, so will not be able to make practice (will come talk to you on Monday, Marek)

Figure 2: A portion of an athlete and coach's shared records in Google Docs showing comments about illness.

This way they can recover without losing too much fitness. If they wait and the injury gets worse, then they risk being out for a longer period of time, and their fitness will decrease." – P2

A similar issue occurs when there is insufficient communication between the coach, athlete and other stakeholders such as sports doctors or psychologists. Coaches will often push athletes too hard when they return from an injury, or athletes will fear that they are losing fitness and come back to practice before they are fully healed. Our participants told us that better communication between coaches and sport doctors would help ensure that an athlete's recovery is carried out correctly to prevent an unnecessary prolonged recovery. P3 describes the issue as "*not getting the right information to the right person*." He further explains:

"*Although the athlete feels healthy, there are underlying problems, such as un-alignments, that if not corrected will cause future injuries." – P3*

This information, if communicated from the sport doctors, could help prevent re-injury or prolonged recovery.

4.1.3 Sleep & Stress

Our participants told us that sleep and stress were factors that had a tendency to affect an athlete's performance on a specific day of training, rather than a longer period of time. Similarly to injuries and illnesses, the affected athlete usually communicates this information to the coach. P2 described a typical scenario where an athlete will begin a workout with minimal sleep. She explains that the athlete will get through the first interval with some difficulty, usually a slower pace than he normally runs at. After the interval, the athlete will tell her that he has not had adequate sleep. At this point the coach explains that she will usually alter the workout or allow the athlete to perform the practice at a later time (provided it doesn't interfere with the overall training goals).

Two of the coaches explained that athletes that are overtired or highly stressed risk negative shifts in their mood and mental state. If they are aware that an athlete is overtired or overly stressed, then they will often alter their current workout, usually by making it easier or more enjoyable. One coach explains:

"I altered workouts without the athlete knowing… I evaluate how the athlete is feeling, and change the workout to something that they would enjoy and be able to complete with a positive attitude." – P1

Altering the workout contributes in two ways. First, the ease in workout volume and intensity will allow the athlete to recovery faster, and thus become less tired. Second, having the athlete complete an easier or enjoyable workout keeps her moral high. When athletes cannot complete a workshop or fall behind in a workout because of stress or sleep, they risk having a negative outlook on the training. This can cause them to lose focus on their goals.

Though all participants mentioned that they evaluated an athlete's sleep or stress, only three of the coaches actually kept record of these factors. Other coaches explained that, while this information was important, it is often tedious to record for every athlete, and provides another layer of information to transcribe.

4.1.4 Mood

An athlete's mood can also have a direct affect on his or her performance. Similarly to sleep and stress, mood is a factor that our participants tried to gauge through communication with their athletes. Through these conversations, a coach can begin to understand how an athlete is adapting to the training and if the athlete is at risk of overtraining. Although six of the coaches noted that mood was important to track, three of the six explained that with big teams this factor is quite hard to evaluate.

For example, P1, who only had a half-dozen athletes, explained that she was able to gauge an athlete's mood through subtle conversation before the workout, even if the conversation was unrelated to the training. Because she knew her athletes at a personal level, she could read many of their emotions and could predict how they would react to certain workouts. In contrast, P4 explains that with a large team of 20-50 athletes, he uses Google Docs to read training notes (written by the athletes) from many of the athletes' pervious workouts (e.g., Figure 2). From these notes, he explains that he can begin to evaluate the effect that the training has on a particular athlete's mood. One of the challenges P4 describes with this method is that it is very time consuming. Going through workouts notes for each athlete is time-consuming and he often only has enough time to evaluate his top athletes.

Four of the coaches mentioned that they also found it important to monitor athletes' moods as they get closer to important races: *"If an athlete's mood is positive going into a competition they are more likely to perform well"* (P4). In contrast, coaches also understand that if athletes' moods are negative they may be overly fatigued or overtrained. From past experiences, one coach explains:

"*Every athlete knows that training is hard, but if the athlete stops enjoying the sport then it won't matter how physically fit they are." - P1*

By understanding an athlete's mood, a coach can alter an athletes program or workout to ensure that the training is best suited for that particular athlete.

4.1.5 Recording Athlete-Specific Contextual Information

In summary, despite the advantage of recording athlete-specific contextual information (as described above), only half of our participants actually recorded this contextual data. The other half of the participants constantly evaluated their athletes and adjusted their training accordingly, but they did not actually record this information. Thus, it was found to be important but too tedious to track. Two of the participants who recorded contextual data did so through Google Docs, one of the participants used an online training system, and another participant recorded these factors either through email or pen and paper. Overall, those who recorded athlete-specific information found it tedious and challenging to do. For example, the coach using the online training system found that even though the system provides explicit areas for athletes to enter contextual factors such as sleep

or caloric intake, much of this data, along with athlete notes, were buried within a particular workout. This made it difficult for him to extract and explore this data at a later point in time. Lastly, coaches who evaluated these factors by pen and paper, email, or through verbal communication, discussed challenges surrounding content curation and the lack of ability to relate the data to a particular workout or training program.

4.2 Goals and Timeline

Participants told us that goals and key races, such as a national championship, are an important part of both training program development and the process in which an athlete completes the planned training. These goals and races act as the focal point for a competitive season and the primary reason for committing to a training program. For instance, P7 describes that developing a training program can be fairly scientific and often requires a certain level of sport-specific knowledge. He further explains that every training program must start with a goal or key race for which the athlete wants to be at his peak fitness level. Once the peak or goal is set, he can begin to work backwards by incorporating necessary rest, weekly intensity levels, and periods of system development into the training program.

These goals, although always kept in mind, are often lost track of during a long training period. For example, P3 describes a circumstance where his athlete's primary goal or peak race was four years away when the athlete would be qualifying for the Olympic Games. He explains that, psychologically, it is hard to keep an athlete like this focused when the development towards the goal is long-term.

Four coaches mentioned that giving an athlete the ability to visualize their goals in relation to their current training would allow them to see the big picture and mentally adapt to future workouts and goals. For instance, P4 explains that his team usually plans to peak for the National Association of Intercollegiate Athletics (NAIA) cross-country championships. He describes how it is mentally beneficial for both him and his athletes to see how many weeks or days of training remains between the current day of training and the goal. He also believes this is important for him as a coach to see as it allows him to evaluate the current status of his athletes and prepare any future training in the given amount of time. He also describes this as being important to his athletes as it allows them to be aware of the goal and understand how the training leading up to the goal will enable them to perform at their peak fitness level.

4.3 Performance Data: Distance and Time

The most commonly collected data types among coaches are distances and time for intervals in a workout, and totals of weekly activity. All of the participants mentioned that these are the primary measures they record as this data provides a basis for analysis and comparison of an athlete's performances and improvements. Much of the workout data is then coupled with the previously described contextual factors that are monitored through verbal communication, evaluation of an athlete's appearance, or athlete notes. We outline each of the types of comparisons coaches found important next.

4.3.1 Long Term, Yearly Comparisons

First, our participants told us that they like to be able to do long term comparisons across two or more years of data. For example, P5 explains that yearly comparisons allow him to develop an idea of a current athlete's fitness in relation to the athlete's fitness during previous years at the same time. Looking at the data over a single or multiple year timeline also allows coaches to see trends in an athlete's performances. For instance, P2 explains how she was able to provide her athlete, who was leaving for the London Olympics, with three weeks worth of workouts for the training camp leading up to the games. To determine what workouts she should give to the athlete, she looked at what workouts led up to the athlete's peak points in previous seasons and used these to structure the training accordingly.

Another example is illustrated by P4 who describes how he uses Google Docs to record and look through an athlete's previous year's performances. From this he can determine when that athlete 'peaked' or reached his maximum potential for that particular season. Knowing this can help him understand what the training volume or intensity was leading up to this peak performance, and try to map it across current or future seasons. P4 finds this especially beneficial, yet the format of using Google Docs can present challenges for analysis because textual data must be compared over time periods.

Our participants also explained that training based on 'peak' times is athlete-specific. For example, P8 explains that each of his athletes will respond differently to training. As a result, a certain amount of volume or rest leading up to a goal or peak race may work well for one of his athletes, but poorly for another. Through data analysis, he can look at these yearly trends and adjust the intensity and rest volumes for each athlete individually. Again, this analysis can be cumbersome because it involves reading through lines of textual notes and creating an assessment.

A similar process is discussed by P2 who analyses both contextual data alongside performance / workout data to predict when his athlete will be in her 'best form' or peak fitness. P2 uses a scientific method that calculates an athlete's fitness, fatigue, and form. The calculation uses input such as, workout duration, intensity, and RPE to generate a number that represents how difficult the workout is. A higher number will result in a greater increase in an athlete's fitness, and consequently a greater increase in an athlete's fatigue. He further explains that as fatigue decays, an athlete's form will increase. This analysis is used by the coach to plan the intensity of workouts in order to gradually lower fatigue, produce higher form, and maintaining fitness while leading up to a peak race.

4.3.2 Short Term, Weekly and Monthly Comparisons

Monthly and weekly comparisons can provide coaches with the ability to see how an athlete is progressing through the current training and evaluate an athlete's short-term fitness leading up to peak or goal races. Both P7 and P8 explain that they will have one specific workout or route that they will have their athlete's complete once or twice a month in order to evaluate an athlete's progression. Because the distance, terrain, elevation and interval number of these workouts is always the same, the only variables that change are the athlete's time and heart rate. From this, P7 explains that he can accurately discover how his athlete is improving. If an athlete's time decreases each month and the average heart rate for these intervals stays the same, then he can tell that the athlete's fitness is improving. In contrast, if an athlete's heart rate is increasing, but the athlete's interval times remain the same, then he can tell that the athlete is having to work harder in order to produce the same outcome.

4.3.3 Performance Comparisons Between Teammates

Three participants described how comparing performance data between athletes on their team could help them determine which athletes to include on a 'travel team'—the people sent to a racing event to compete. For instance, P4 explains that he can only select

seven women and seven men to bring to the NAIA Championships. To determine which athletes to send, he evaluates the athletes' performances in the months leading up to race. He is often in the situation where he is deciding between two athletes for the last spot on the team. In this case, he will look at which of these athletes has been progressively getting faster during the last couple months of training. Usually, he will choose to take the athlete who is still improving over the one who has already peaked and trying to maintain his or her fitness. This typically equates to better competition outcomes for the team.

5 DISCUSSION

From the interview analysis results we were able to gain insight into the types of athlete-specific information that coaches are tracking, monitoring, and analyzing. We were also able to further understand how coaches are using this information to refine and adjust an athlete's training program, insuring that the athlete achieves peak fitness at the opportune time period. Our study also revealed specific areas where improvements in data collection, communication, and analysis tools could enhance the training process for both coach and athlete, and provide coaches with a greater opportunity to develop training programs that best fit each individual athlete. Similarly, this offers suggestions for self-coached athletes about what they may find relevant to record and analyse in relation to their training.

5.1 Including Athlete-Specific Contextual Information

First, athlete-specific contextual information, such as rate of perceived exertion, illnesses and injury, sleep, stress, and mood, coupled with workout data, provides coaches and athletes with the potential to analyze workouts or training programs in greater detail. Some applications allow for athletes to input contextual factors in the form of a textual notes, which is often coupled with performance-related workout data. Yet this process of data collection poses problems. Documenting this data as workout notes gives the athlete or coach the ability to reflect upon many factors in an open ended format; however, they are not forced (or suggested) to explicitly include certain factors that might turn out to be relevant. Notes can also be tedious to enter time after time, and more importantly, can be very time consuming for a coach of several athletes to read, remember, and act on. Coaches of larger teams might miss important data such as injury, sickness, or fatigue. Furthermore, the qualitative nature of this contextual information can prevent a coach from using the data to actively monitor their athletes as well as perform any type of analysis of these factors outside of a particular workout.

Together, this suggests that personal informatics applications for amateur athletes and coaches could prompt users to input relevant contextual information as identified by our coach participants. Moreover, a mix of qualitative and quantitative data input may be valuable as a way to easily compare data points across time periods (via quantitative data) and also understand any additional contextual information (via qualitative data) around it. This could allow coaches to improve their record keeping and analysis. For those amateur athletes who are self-coached, this could provide them with a better understanding of what they can record and act on to improve their self-coaching methods.

5.2 Comparing Time Periods for Training Programs

Workout data, such as interval times and distances, provides coaches and athletes with the opportunity to assess their current fitness and use the results to appropriately plan future training. Much of this data, unlike contextual data, is quantitative and can be easily compared and measured. Many of the current online personal informatics systems focus on the process of analyzing a particular workout. While this can be beneficial, many coaches are focused on yearly, monthly, or weekly comparisons rather than workout-level comparisons. By giving the coach the ability to visualize aspects of an athlete's training over these longer time periods, a coach can begin to develop trends and patterns in an athlete's data. In addition, adding a layer of contextual elements, such as fatigue, RPE, or mood to these visualizations affords for further understanding of how each particular athlete responds to the training intensity.

If coaches were presented with contextual factors as a means to visually monitor a group of athletes, they could not only discover particular trends in an athlete's training, such as a long period of fatigue or soreness, but could potentially begin to act on factors before they lead to lead to larger issues such injury or sickness. For example, from communicating with an athlete after several workouts, a coach can begin to understand how fatigued an athlete becomes as a result of a certain amount of training. If the coach could track and visualize these factors and communication, then it would become easier to see an athletes fatigue or mood over time, and plan future training accordingly. Furthermore, if coaches were provided with a visual overview of their athletes' current contextual factors, rather than having to explore past workouts to better understand a particular athlete, coaches could easily evaluate any athletes that are overtired or recovering from injury. From this overview, coaches could alter an athlete's workout beforehand, thus preventing the athlete from completing a workout that would become counterproductive.

Training programs certainly play a crucial role in an athlete's season as they help structure the development of specific sport-related systems. The training programs that coaches create are aimed at ensuring that the athletes are in their peak fitness for the more important races in the competition season. In the majority of current athletic-informatics systems, there is a lack of focus on planning and development of training programs as much of the planning is focused on the creation of singular workouts. Providing a system that integrates workout and contextual data with the creation of training programs would provide coaches and self-trained athletes with the opportunity to visualize the athletic response to the planned training, and thus refine future programs. Furthermore, the relationship between recorded workout data and planned training can be visualized to provide coaches and athletes with an understanding of the completed training, and the development towards goals and key races.

5.3 Communication Between Coach and Athlete

As can be seen, the communication of contextual information between athlete and coach is very important. Without it, the suggestions we have already provided would not work as the data would simply not be there for analysis. All of the coaches we interviewed used face-to-face interactions to communicate with their athletes and learn about the contextual factors that might affect the athletes' training and performance data. Face-to-face interactions are beneficial, yet some of the relevant information may come at times when the coach is not around. Athletes must be able to remember this information and convey it to the coach. Some athletes used journals or notes to circumvent this where they would then share the data with the coach at a later point. Yet this relies on the fact that athletes remember to record information between workouts and know what is relevant to record. It also means that athletes must remember to present this information to their coaches.

Clearly this suggests opportunities for groupware applications that can facilitate information sharing between coaches and athletes in-the-moment or on a more frequent basis. For example, applications could prompt athletes with the information that would be relevant for them to record when the coach is not around, such as soreness, sleep, fatigue, or moods. This information could then be shared with the coach automatically through a groupware system. Coaches could even ask for additional information if they feel they are not certain of the situation. This in-the-moment communication may be a more effective tool to support the monitoring and recording of athlete-specific information to aid training programs. Turning to commercial-systems, we see that this is not a current emphasis. Athletes are able to post performance data online for others to see, however, there is no emphasis on athlete-to-coach exchange of information and discussion of contextual information.

Of course, there are privacy challenges as athletes do not want to be over-monitored when it comes to their lifestyle and personal information. Systems would need to carefully allow athletes to reveal only the information that they feel is relevant to their training program, which could be informed by the coach offering suggestions as to what he or she might like to know about. It may also be beneficial for select information to be shared with sports doctors such that they can understand the situation leading to an injury. Similarly, information from sports doctors could also be provided to coaches and athletes through a shared application, such that a proper understanding of the injury and recovery process could be understood. This could, in turn, be worked in to the training program created by the coach or self-coached athlete.

6 Conclusion

This paper has explored the role of personal informatics in the coaching and training of amateur endurance athletes. The ability to access such data begins to bridge the gap between sport science and the athlete as personal informatics applications provide individuals and amateur athletic coaches with the opportunity to perform complex analysis on athletic performances, and the ability to tweak or structure future workouts accordingly. The research evaluates the current use of technology within this athletic community and develops an understanding of potential areas where these personal informatics and sport specific data can be better integrated with the athletic training process.

Our results show that personal informatics applications for athletes could be broadened to integrate additional contextual information alongside performance-based information. Moreover, this data could be presented to coaches or athletes in a way that allows them to compare across broader time periods (e.g., weekly, monthly, yearly) rather than at a workout level, where applications could even provide training program suggestions based on these comparisons. We also see the need for groupware systems focused on personal informatics to incorporate better information exchanges opportunities for coaches and athletes such that valuable information is not forgotten about, miscommunicated, or ignored altogether.

Future research in this area should continue to explore the role of contextual factors in conjunction with performance data to understand how personal informatics applications should be properly designed to present, visualize, and offer comparison tools for coaches and athletes.

References

[1] Anderson, I., Maitland, J., Sherwood, S., Barkhuus, L., Chalmers., M., Hall, M., Brown, B., and Muller, H. Shakra: Tracking and Sharing Daily Activity Levels with Unaugmented Mobile Phones, Mobile Networks and Applications, 12(2-3), Kluwer Academic Publishers, 185-199.

[2] Assogba, Y., and Donath, J. Mycrocosm: Visual Microblogging Proceedings of the Hawaii International Conference on System Sciences, 1-10, 2009.

[3] Borg, G. Perceived exertion as an indicator of somatic stress. Scandinavian Journal of Rehabilitation Medicine, 2 (2), 92-98, 1970.

[4] Braun, V. and Clarke, V. Using thematic analysis in psychology, Qualitative Research in Psychology, 3 (2), 2006.

[5] Consolvo, S., McDonald, D.W., Toscos, T., Chen, M., Froehlich, J., Harrison, B., Klasnja, P., LaMarca, A., LeGrand, L., Libby, R., Smith, I., and Landay, J. Activity Sensing in the Wild: A Field Trial of Ubifit Garden, Proceedings of the Conference on Computer Human Interaction (CHI), ACM Press, 1797-1806, 2008.

[6] Gemmell, J., Bell, G., and Lueder, R. MyLifeBits: a personal database for everything, Communications of the ACM, ACM Press, 88-95, 2006.

[7] Givaerts, S., Duval, E., Verbert, K., Pardo, A. The Student Activity Meter for Awareness and Self-reflection. Conference on Computer-Human Interaction, ACM Press, 869 – 864, 2012.

[8] Guest, G. Applied thematic analysis, Thousand Oaks, California: Sage, 2012.

[9] Hodges, S., Williams, L., Berry, E., *et al*., K. SenseCam: a Retrospective Memory Aid, Proceedings of the Conference on Ubiquitous Computing (Ubicomp), Springer, 177-193, 2006.

[10] Houmard, J.A. Endurance Athletes: What is the Optimal Training Strategy? International Journal of Sports Medicine, 30(5), Georg Thieme Verlag KG Stuttgart, 313-314.

[11] Kellmann, M. Underrecovery and overtraining: Different concepts, similar impact? In M. Kellmann (Ed.), Enhancing recovery: Preventing underperformance in athletes 3-24, 2002.

[12] Human Kinetics.Li, I., Dey, A. K., and Forlizzi, J. A Stage-Based Model of Personal Informatics Systems. Conference on Computer-Human Interaction, ACM Press, 557-560, 2010.

[13] Li, I., Dey, A. K., and Forlizzi, J Understanding My Data, Myself: Supporting Self-Reflection with Ubicomp Technologies. ACM International Joint Conference on Pervasive and Ubiquitous Computing (Ubicomp), 405-414, 2011.

[14] Li, I., Dey, A. K., and Forlizzi, J. Using context to reveal factors that affect physical activity. ACM Transactions on Computer Human Interactions, 19, 1, ACM Press, 2002.

[15] Lin, J.J., Mamykina, L., Lindtner, S., Delajoux, G., and Strub, H. Fish'n'Steps: Encouraging Physical Activity with an Interactive Computer Game, Proceedings of the Conference on Ubiquitous Computing (Ubicomp), Springer, 261-278, 2006.

[16] Malkinson, T. Current and Emerging technologies in endurance athletic training and race monitoring. Science and Technology for Humanity, IEEE Toronto International Conference, 581-586, 2009.

[17] Pate, R. and Branch, D. Training for Endurance Sport, Medicine and science in sports and exercise, 24, 1992.

[18] Rearick, M., Creasy, J., and Buriak, J. Avoid Overtraining in Young Athletes, Journal of Physical Education, Recreation & Dance, 82(5), May 2011, Academic Alliance for Health, Physical Eduaction, Recreation and Dance, 1-60.

[19] Saupe, D., Luchtenberg, D., Roder, M., Federolf, C. Analysis and visualization of space-time variant parameters in endurance sport training, Symposium Proceedings 6th IACSS, 252-256, 2007.

[20] Venter, R. Rest, and Specifically Sleep, Play a Major Role in Athletic Performance. South African Journal of Continuing Professional Development, 26(1), 2008.