

# Integrating Physical Activity Data with Electronic Health Record

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**Keywords:** HL7 Fast Health Interoperability Resources (FHIR), Physical Activity Resource, EHR Physical Activity, OpenEMR, Exercise, Wearables.

**Abstract:** Wearables allow individuals to track, analyze, and visualize their physical activities and associated data such as vitals, activity information, etc. across time. But, none of this activity data is anywhere to be found in an electronic health record - the primary source of patient medical data for the healthcare providers. This inability doesn't allow experts to view the complete health summary of an individual and also, activity data can play a key role in healthcare decisions. This problem is due to the lack of standards that can capture activity data from disparate sources (e.g., wearables, smart watches, trackers, etc.) and integrate it with an EHR. This research article identifies and provides a detailed analysis of the key factors contributing to the problem. Based on the detailed analysis, we design an interoperable model by leveraging HL7 FHIR standard to capture activity data from wearables and develop it using FHIR HAPI - an implementation of HL7 FHIR. This initial prototype is tested by capturing Fitbit data and integrating it with OpenEMR - an open source EHR.

## 1 INTRODUCTION

Digitalization of healthcare data in the form of Electronic Health Record (EHR) eliminated many healthcare issues and is leveraged by the industry to capture, aggregate, and analyse the patient data. Currently, many EHR systems, both proprietary and open-source, allow providers to capture a variety of patient data such as diagnosis, encounters, observations, procedures, medications, family medical history, etc. The patient data can be shared across healthcare systems using different healthcare standards such as ASTM CCR, Health Level 7 (HL7) CCD (D'Amore et al., 2011), HL7 V2 and V3 (Boone, 2011, Dolin et al., 2001) messaging format, and HL7 FHIR (Saripalle, *in press*). However, the physical activity data of a patient is not captured in an EHR and is not shared across diverse healthcare systems. Physical activity is defined as "*any bodily movement produced by skeletal muscles that result in energy expenditure*" (Caspersen, Powell & Christenson, 1985). Exercise is a subset of physical activity which is defined as "*a planned, structured, and repetitive and has as a final or an intermediate objective the improvement or maintenance of physical fitness*" (Caspersen et al., 1985). Both physical activity and exercise will be referred as to

"activity" for the rest of the article unless stated explicitly.

Before wearables, tracking activities and quantifying their output was practically impossible or expensive for an individual/patient. Hence, there is none or minimal activity data recorded in the health records. However, the introduction of wearables and smartwatches (e.g., Fitbit, Apple Watch, LG Watch, etc.) have revolutionized the personal health space and the behavior/attitude of the consumers towards activities. Using these affordable digital instruments, an individual can track their physical activity (e.g., walking, running, etc.) and any associated data (e.g., heart rate, calories, distance, elevation, route, time, etc.). According to market analysts (Hunn, 2015, Kaul, Wheelock, 2015), there is an accelerating market for wearables where the valuations are expected to reach ~30 billion by 2020 from ~\$600 million in 2013. Researchers (Shin, Jarrahi, Nov 15 2014, Hillsdon, 2015, Fanning et al., 2012, Lim et al., 2011) also found evidence that the wearables served as a valuable tool for quantifying and visualization an individual's physical activities and provided them motivational affordances to do more.

Even as individuals can track their activities and quantify its output, healthcare providers cannot see

this data in an EHR. The primary reason is due to the lack of an interoperable model/structure within the existing healthcare standards that can capture activity data. These are the same healthcare standards that are used to share EHRs. Figure 1 renders the current wearable infrastructure and it's working. In most cases, logs are used to record the exercise routine/plan, a non-digital format facing the same issues as paper-based medical records. Activity data captured using the wearables (e.g., Fitbit, most popular among wearables) is synchronized to the organization data repositories through a mobile app (e.g., Fitbit, LG Sport, etc.) and is accessible via an API (e.g., Fitbit or Google Fit API) but is formatted in the organization own data format. In the case of Apple Watch, data is only accessible within iOS ecosystem using Apple HealthKit or download through its Health App, making it difficult to access the data outside the iOS environment. In Android, the devices use Google Fit to record and access the activity data. Most of the other fitness wearables (e.g., Garmin, etc.) fall under the same pattern – record, report, and access the data via an API if provided or download the data. From Figure 1, it is evident that the activity instruments, digital or non-digital, collect (and report) data in a non-standard format and report the data to a proprietary data store, creating data silos. These data repositories or the devices cannot communicate the captured data with a healthcare information entity such as an EHR due to the lack of an agreed “standard” to capture and share the activity and any associated data. Focusing on integrating individual devices with an EHR out of the box is unfeasible, aunting, and practically not scalable.

Another issue due to the inability to integrate activity data with an EHR is that the experts cannot provide evidence-based physical activity plans, exercise routines, etc. For example, an individual, say, John Doe, age 25 with no serious medical condition approaches a trainer to improve his fitness. Most of the trainers use their knowledge and experience to design a exercise routine to help John Doe reach his/her goal. How will the trainer prove the provenance of the routine? What kind of evidence can the trainer provide to John Doe that supports the plan or at least in majority cases? John Doe might have a positive attitude towards the exercise routine if the trainer shows evidence that the exercise routine worked previously with other individuals. In biomedical and health informatics, questions related to the patient's treatments or care can be answered with clinical evidence. This evidence is obtained by analyzing copious amounts of de-identified aggregated patient data using various computational algorithms and techniques. The same cannot be said about physical activity and exercise routine/plan(s).

The aim of this research is to design and develop an interoperable model/structure using existing healthcare standard to capture activity data and share it across healthcare information systems. The rest of the paper is organized as follows. Section 2 provides the background knowledge and analysis of the current situation. Section 3 presents the solution using the HL7 FHIR and OpenMRS – an open source EHR. Section 4 summarizes the research.

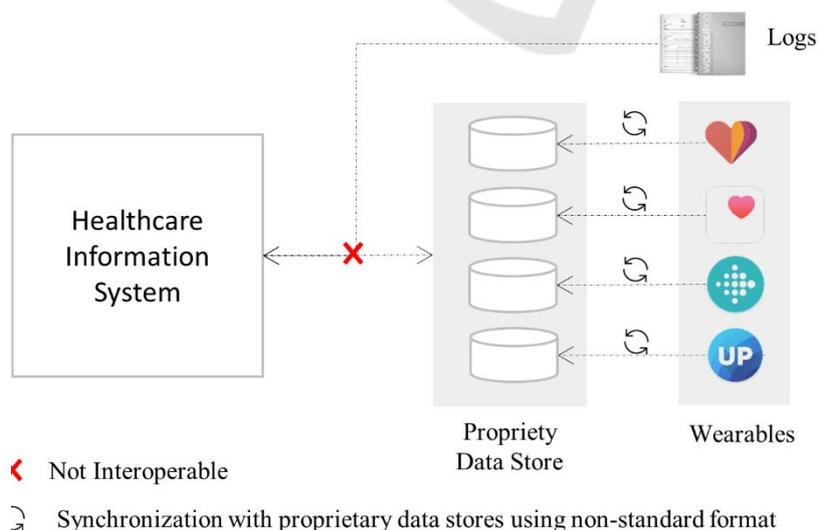


Figure 1: Interoperability issues with current physical activity and exercise digital and non-digital instruments.

## 2 BACKGROUND AND ANALYSIS

Experts unanimously agree that physical activity has many health benefits and numerous research studies spanning across multiple decades has proven to show its impact the overall health of an individual and nation's economy. With the goal to improve the activity level of individuals across the United States, in 2007, the American Medical Association and the American College of Sports Medicine (ACSM) collaborated to launch the program - Exercise is Medicine (EIM) (Lobelo et al., 2014). The goal of the program is to make physical activity a standard and adapt scientifically proven benefits of physical activity into the mainstream healthcare. The idea is for the physicians to access the activity level of the patient (use of the Physical Activity Vital Sign (PAVS) questionnaire (Lobelo et al., 2014, Sallis, 2011) during the patient's encounter and *prescribe* physical activity based on the identified health risks and ACSM evidence-based guidelines. The physical activity prescription, similar to medication prescription, must be saved and tracked along with other data. The most effective way to achieve this goal is to integrate activity data with an EHR. The intention of the EIM is congruent with the research statement and supports the need for healthcare standard(s) to integrate the activity data with an EHR.

Beyond EIM framework, there are only a few research studies that have identified and reported the need to save physical activity data for longitudinal healthcare analysis and benefits. Sallis (2011) pushed to treat physical activity as a vital sign. Physicians must record and observe the patient's physical activity levels during their medical visits once recognized as a vital sign by the healthcare community. Coleman et al., (2012) presented facts and validity of Exercise Vital Sign (EVS), similar to PAVS, for its use in an outpatient electronic medical record. After analysing the current research and healthcare standards, the primary reason for the interoperability issues is due to the lack of agreed healthcare standards, both *structural* and *semantic*, for representing and sharing activity data. As the standards are a foundation for interoperability, it's surprising that the experts have not yet designed an interoperable standard to capture physical activities and exercises. Without an agreed standard, it's not feasible to capture, share and integrate the activity data into the healthcare systems. Few standards are scalable and can be extended to meet various healthcare requirements, in our case capture activity

data. For instance, HL7 V2 (Boone, 2011) messaging format is a pipe (|) and hat (^) encoding format that allows clinicians to exchange data. However, this standard is not supported by a software model with a well-defined structure and semantics. Due to this drawback, experts developed the HL7 V3 (Boone, 2011) messaging format. Thus, it doesn't add any value to extend the HL7 V2 format to achieve our goal. The HL7 V3 is built using HL7 Reference Information Model (RIM) (Boone, 2011) – a sound object-oriented model with a well-defined structure, semantics, and constraints that can be extended. The current HL7 RIM model can be repurposed to capture and communicate a limited set of activity data. For example, activities such as jogging, swimming, etc. and the vitals generated during the activities can be represented and communicated using HL7 V3 messages. Figure 2a shows the activity jogging (the subject of the message) and heartbeat (outcome (OUTC) relationship), an outcome of the subject in HL7 V3 format.

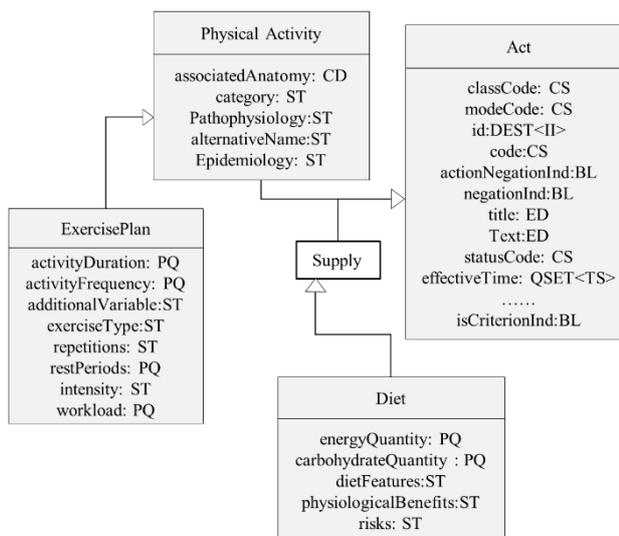
Saripalle (2017) extended the HL 7 RIM model with required classes to capture the activity data. Later, HL7 V3 messages were constructed based on the extended model to share the activity data across healthcare systems that accept HL7 V3 messaging format. Figure 2b shows the extended model. The classes, PhysicalActivity and ExercisePlan, that capture the required data. authors to use this document for the preparation of the camera-ready. There are two key lessons learned from this research. First, the HL7 RIM is a complex model that can be difficult to comprehend. Further, understanding HL7 V3 messaging format has a steep learning curve that requires expertise in computing. Second, there are only a few open-source healthcare systems and tools, specifically EHR's, which can be extended and are designed to accept HL7 V3 messages. This makes implementation of the research very difficult.

The knowledge required to design the new classes (Figure 2b) to extend the RIM is adapted from PhysicalActivity and ExercisePlan schemas defined by Schema.org. Schema.org (2012) is an open source effort to define schemas/data structures to describe any data, especially the data published on the web. Schema.org describes, i.e., provide schema/structure for numerous concepts (e.g., Person, ScholarlyArticle, Book, Organization, etc.) across various domains (e.g., Auto, Health, Books, Biology, etc.). Currently, most of the data published on the web is unstructured. The developers use the Schema.org schemas to annotate (using Microdata or

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  <act classCode="ACT" moodCode="EVN">
    <entryRelationship typeCode="SUBJ" inversionInd="false">
      <observation classCode="OBS" moodCode="EVN">
        <code code="1968006" codeSystem="2.16.840.1.113.6.96"
          displayName="Jogging" codeSystemName="SNOMED"/>
        <entryRelationship typeCode="OUTC" inversionInd="true">
          <observation classCode="OBS" moodCode="EVN">
            <templated root="2.16.80.1.113883.10.20.2.32"/>
            <code code="248646004"
              codeSystem="2.16.840.1.113.6.96"
              displayName="Heart Beat"/>
            <statusCode code="Completed"/>
            <effectiveTime value="20160714"/>
            <value xsi:type="PQ" value="96"
              unit="mm[Hg]"/>
          </observation>
        </entryRelationship>
      </observation>
    </entryRelationship>
  </act>
</entry>
  
```

(b) HL7 V3 message representing the activity jogging and resultant vital data using the RIM model Act and Observation class.



(a) Extended HL7 RIM model to capture activity data.

Figure 2: HL7 V3 message format and extended HL7 RIM model.

RDFa or JSON-LD formats) their data before publishing. This also allows machines to understand and link data efficiently. Many modern websites use Schema.org to annotate their webpages to provide meaning to their data and also make the website search engine friendly. The PhysicalActivity and ExercisePlan schemas from the Schema.org that are adapted by Saripalle (Saripalle, 2017) to design the new RIM classes (Figure 2b) and are also used for this research. Similar to the Schema.org, Open mHealth (Open mHealth, 2015) is a data-driven approach to provide schemas specifically for describing, collecting, and sharing healthcare data such as blood pressure, body weight, body height, heart rate, etc.

Further, apart from developing the structural standard(s) for activity data, the idea of this research, experts must also define semantic standard(s) to standardize the physical activity and exercise vocabulary. Few existing terminologies capture concepts related to the physical activity and exercise. For example, SNOMED (2007) is an internationally recognized biomedical semantic terminology that captures concepts spanning across multiple clinical disciplines. For example, jogging (code 1968006), running (418060005), walking (129006008), chest press exerciser (46778600), etc. However, currently, there is no dedicated standard semantic terminology that comprehensively captures the concepts of physical activities and exercises.

Designing and developing standards itself doesn't solve the problem. The standards also need support from the healthcare community, information technology, healthcare experts, public and private organizations. Most importantly, the healthcare community must adopt the new/extended standard to existing systems and applications. The healthcare experts might have to tweak their protocols, best practices, and include physical activity check during a regular patient's visit.

### 3 INTEGRATING ACTIVITY DATA WITH EHR USING HL7 FHIR

To capture the activity data and seamlessly integrate it with a healthcare system such as an EHR, this research will leverage HL7 Fast Health Interoperability Resource (FHIR) (HL7, 2015) – the new HL7 member, OpenEMR – an open source electronic health record system (OpenEMR, 2001) and schemas defined by Schema.org and Open mHealth. The research design has two phases. First, extend FHIR to design a new model to capture the activity data. Second, implement the new FHIR model and interface it with the OpenEMR. This research doesn't handle semantic standard(s) required for the physical activity and exercise.

Briefly, the HL7 FHIR standard is designed by combining the HL7 RIM model, lightweight HTTP-based RESTful web services and the lessons learned from using HL7 V3 format. HL7 FHIR is a mashup of HL7 RIM and REST protocol with backward compatibility with the HL7 V3. The atomic unit of FHIR is a *Resource*. The health data in the FHIR environment is captured and shared as an FHIR resource. The FHIR standard defines multiple resources to represent different types of healthcare data. For example, MedicationStatement resource captures a patient's prescription, Encounter resource captures patient-provider visit information, Observation resource captures vital data (e.g., heart rate, blood pressure, pulse, BMI, weight, etc.) or symptom data, DiagnosticReport captures test results information including images, and Vision resource captures patient's optical data. HL7 FHIR also has resources to capture administrative and health insurance aspects such as Claim, Coverage, PaymentNotice, etc. For comparison, FHIR resources are equivalent to various sandwich ingredients such as bread, spreads, vegetables, meat, sauces, etc. As the different ingredients are combined to make a user's sandwich, multiple FHIR resources are aggregated to build a patient record or an EHR. Figure 3 exemplifies the usage of individual FHIR resources to build a patient's record. Currently, FHIR defines 117 resources that can be categorized into clinical (e.g., Condition, Observation, NutritionOrder, etc.), foundation (e.g., CapabilityStatement, Provenance, etc.), base (e.g., Patient, Person, Organization, etc.), financial (e.g., Claim, Coverage, etc.), and specialized (e.g., ResearchStudy, Questionnaire, etc.). It's beyond the scope of this paper to further delve into the fundamentals of FHIR standard and its inner workings. For further documentation and a complete list of the FHIR resources can be accessed at the FHIR specification website (HL7, 2017).

The HL7 FHIR standard designers are aware that the current set of resources might not meet all the current and future healthcare and policy requirements. Thus, the FHIR design team ensured that the standard is extendable, i.e., experts can define new FHIR resources or existing resources can be modified to meet any requirement. In software engineering terms, FHIR embraced the classic open-closed principle. This research will leverage this feature to design a new FHIR resource to capture the patient's physical activity and exercise data and

share it across healthcare information systems. The context and knowledge required to define the new FHIR resource, named PhysicalActivity, that captures the activity data is obtained from the PhysicalActivity and ExercisePlan schemas defined in Schema.org, PhysicalActivity and related schemas from Open mHealth, PAVS questionnaire, and knowledge from the experts in the field of exercise science. Table 1 shows the primary attributes of PhysicalActivity and ExercisePlan (some attributes are ignored as they are unrelated to the research goal) defined by Schema.org.

Table 1: Attributes associated with PhysicalActivity and ExercisePlan schema defined in Schema.org.

Physical Activity	
Attribute Name	Explanation
associatedAnatomy	The anatomy of the underlying organ system or structures associated with this entity.
category	A category this activity belongs to
epidemiology	The characteristics of associated patients, such as age, gender, race etc.
code	The code from a controlled vocabulary or ontology such as ICD, MeSH, SNOMED-CT, etc.
recognizingAuthority	The organization that officially recognizes this activity
pathophysiology	Changes in functions associated with this activity.
Exercise Plan	
Attribute Name	Explanation
activityDuration	Length of time to engage in the exercise.
activityFrequency	How often one should engage in the exercise.
exerciseType	Type(s) of exercise, such as strength training, aerobics, etc.
intensity	Degree of force involved in the exercise. E.g., heartbeats
Repetitions	Number of times one should repeat the activity.
Workload	Measure of the exercise output or energy expenditure

On further analysis, the attributes of the PhysicalActivity schema defined by Open mHealth are a subset of PhysicalActivity schema attributes of Schema.org. The Open mHealth doesn't provide a standard data structure to capture exercises. Apart from the ExercisePlan schema from Schema.org, the research also considered the paper-based (exercise

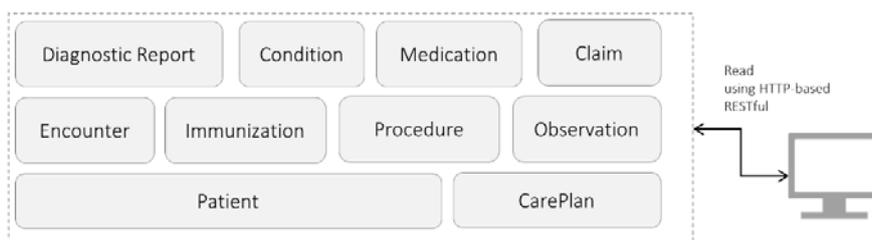


Figure 3: FHIR resources are aggregated to define a patient profile.

logs) structure followed by various organizations (e.g., LA Fitness, Gold gym, etc.), and expert's knowledge into the new FHIR resource design consideration.

Figure 4 shows the PhysicalActivity FHIR resource. The exercise entity is modeled as an inner element of the PhysicalActivity resource as an exercise is a structured and repetitive physical activity in the exercise science (Caspersen et al., 1985). In an object-oriented language, the exercise element has a composition relationship with PhysicalActivity resource. Figure 4 provides a detailed description of each attribute in the PhysicalActivity resource and the data it captures. The attributes vital and patient are of type Observation and Patient FHIR resources respectively. The types of other attributes are FHIR defined datatypes such as Identifier, Quantity, CodeableConcept, string, etc. As previously stated, some attributes (Table 1) from PhysicalActivity and ExercisePlan schemas from Schema.org are in the PhysicalActivity resource. The designed resource also captures the crucial data requested in the PAVS questionnaire through the attributes activeTime and Workload (e.g., calories burned). The PhysicalActivity resource can also be extended, like any other FHIR resource to meet any future requirements.

The second phase is the implementation of the designed research and integrating the captured data with an EHR – OpenEMR. The HL7 FHIR is only a standard specification, but not an executable software. The research used the FHIR specification to design the new PhysicalActivity FHIR resource, but to prototype the solution this research will use HAPI FHIR (Velykis, 2014). The HAPI FHIR is an open-source Java implementation of HL7 FHIR specification that has both server and client. The Open Medical Record System (OpenEMR) is used to integrate the activity data captured as an FHIR resource. The OpenEMR is chosen for this research due to an active community, has a larger audience, and focused on natively supporting the FHIR standard. The OpenEMR is modified to accept the

new FHIR resource, persist the data and display the data on the system.

Figure 5 shows the architecture of the implementation. The HAPI server is the main module of the architecture interfacing with the Translator and the OpenEMR database. The Synchronizer extracts the activity data using the wearable API (e.g., Fitbit API) and authenticating using the provided OAuth credentials from the respective wearable datastores and pass the data to the Translator. The Translator translates the activity data into an instance of PhysicalActivity FHIR resource and passes it to the HAPI server. Currently, the implementation can handle Fitbit, Jawbone data and Google Fit data. The FHIR server saves the data in the OpenEMR database using its OpenEMR API and physician can access the same data using OpenEMR user interface. The wearable, with an API, has to be configured only once and the data is extracted periodically. Currently, the wearable configuration, primarily authentication, needs to be done at the programming level, but not through OpenEMR UI. As the diverse activity data formats are translated into an FHIR resource, any healthcare application that supports the extended FHIR standard can replace the OpenEMR. Also, the designed research solution is in line with the EIM solution the experts are seeking. The implemented solution is accessible at <http://umls.itilstu.edu:8100/openemr/index.php> and further details are available on request. Figure 6 (top) shows a screenshot of the OpenEMR physician interface displaying “Physical Activity” (bottom right) as a member of any other medical entity such as medication, allergy, prescription, etc. Figure 6 (below) shows the physician a quick snapshot of the weekly summary (calories burned and time in minutes) which is equivalent to PAVS.

## 4 CONCLUSIONS

This research has identified and reasoned the need to

Name	Flags	Card.	Type	Description & Constraints
PhysicalActivity			DomainResource	Physical activity model to capture activity data
identifier	Σ	0..1	Identifier	Primary identifier for the activity
name[x]	Σ	1..1		Name of the activity, either a string or a code
nameString	Σ	1..1	string	
nameCode	Σ	1..1	CodeableConcept	
alternativeName	Σ	0..*	string	Alternative names for this activity
description	Σ	0..1	string	Textual description of the activity
associatedAnatomy	Σ	0..*	CodeableConcept	Associated organ system or structures impacted with this activity
pathophysiology	Σ	1..1	string	Changes in the normal mechanical, physical, and biochemical functions that are associated with this activity.
vitals	Σ	0..*	Observation	Associated vitals such as heart rate, blood pressure, etc.
workload	Σ	0..1	Quantity	Measure of the activity output or energy expenditure
activeTime	Σ	1	Quantity	Active duration – an essential question in PAVS
device	Σ	0..1	Device	Device used for this activity
patient	Σ	0..1	Reference (Patient)	Reference to a Patient who performed this activity
exercise	Σ	0..*	BackboneElement	Any exercise(s) performed during this activity
activityDuration	Σ	0..1	Quantity	Duration of the performed exercise
name	Σ	1..1	string	Name of the exercise
intensity	Σ	1..1	string	Quantitative intensity, e.g. weight, calorie, etc.
volume	Σ	1..1	integer	Sets or Volume of the exercise
restPeriods	Σ	1..1	Quantity	Rest period after the exercise
associatedAnatomy	Σ	0..*	CodeableConcept	Associated organ system or structures with this exercise

Figure 4: Physical Activity FHIR resource.

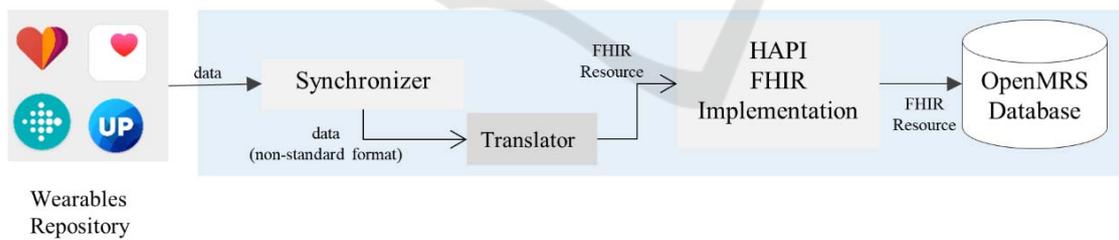


Figure 5: Software architecture of the modified OpenEMR system with HAPI FHIR to integrate physical activity and exercise data.

standardize activity data format and integrate the data with a healthcare information systems, such as an EHR, to provide a patient’s complete health summary to the healthcare provider to make an informed decision. To this end, the research identified that the inability to integrate activity data captured by various instruments (e.g., wearable, smart watched, logbooks, mobile apps, etc.) with an EHR or any other healthcare information system is due to lacks of agreed interoperable structural

standards to represent activity data. Based on the analysis, background knowledge and previous research, lessons from EHR development, and feedback from multiple experts (exercise and health sciences), this research designed an interoperable model, PhysicalActivity resource (Figure 4), by leveraging HL7 FHIR and schemes from Schema.org and Open mHealth to capture activity data. The PhysicalActivity resource is implemented using HAPI FHIR, a client-server implementation of the

HL7 FHIR specification. The research is demonstrated (Figure 5) by extracting the Fitbit data via Fitbit API, translating the data into PhysicalActivity resource and integrating it with OpenEMR - an EHR. Once in the digital format within an EHR, the activity data can be de-identified and aggregated to build large activity datasets allowing researchers to apply data-driven techniques to derive actionable knowledge in the field of health sciences and beyond.

The work presented is an initial step on a long path. Currently, we are evaluating wearables and trackers working on Google Fit and will work our way towards other wearables such as Samsung, Garmin, etc. The next step worthy of pursuing would

integrated with an EHR and address any security, privacy and legal concerns.

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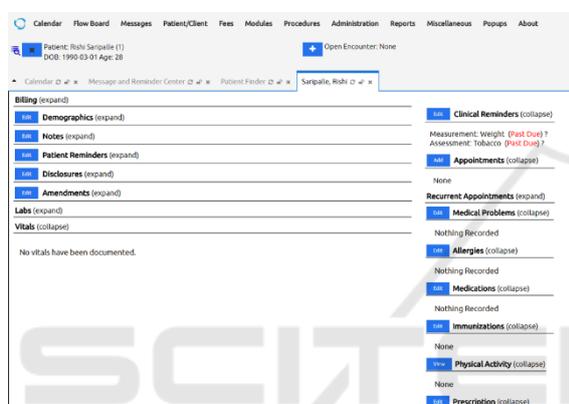
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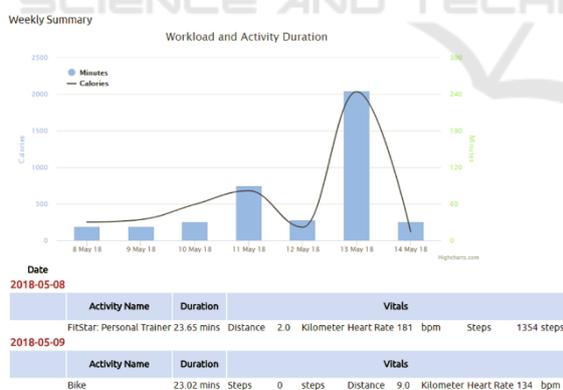
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(b) OpenEMR with physical activity.



(a) Physical activity weekly summary.

Figure 6: Modified OpenEMR to include physical activity and exercise data.

be to propose the PhysicalActivity FHIR resource to the FHIR committee for considering it in the standard after conducting feasibility and acceptability analysis. In the prototyped architecture (Figure 6), the Synchronizer extracts the data and Translator translates it to the FHIR resource. Research is required to understand how this process can be

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