



Universiteit  
Leiden  
The Netherlands

## Development of machine learning: derived mhealth composite biomarkers for trial@home clinical trials

Zhuparris, A.

### Citation

Zhuparris, A. (2024, June 13). *Development of machine learning: derived mhealth composite biomarkers for trial@home clinical trials*. Retrieved from <https://hdl.handle.net/1887/3763511>

Version: Publisher's Version

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded  
from: <https://hdl.handle.net/1887/3763511>

**Note:** To cite this publication please use the final published version (if applicable).



# DEVELOPMENT OF MACHINE LEARNING DERIVED MHEALTH COMPOSITE BIOMARKERS FOR TRIAL@HOME CLINICAL TRIALS

© Ahnjili ZhuParris 2023

Cover illustration: Peter van Dijk

Design: Caroline de Lint, Den Haag (caro@delint.nl)

All rights reserved. No parts of this thesis may be reproduced, distributed, stored in a retrieval system or transmitted in any form or by any means, without prior written permission of the author.

The printing of this thesis was financially supported by Centre for Human Drug Research.

Proefschrift

ter verkrijging van  
de graad van doctor aan de Universiteit Leiden,  
op gezag van rector magnificus prof.dr.ir. H. Bijl,  
volgens besluit van het college voor promoties  
te verdedigen op donderdag 13 juni 2024  
klokke 13.45 uur

door  
Ahnjili ZhuParris  
geboren te New York, Verenigde Staten  
in 1990

**PROMOTERS**

Prof. Dr. G. J. Groeneveld

Prof. Dr. Ir. W. Kraaij (*Leiden Institute of Advanced Computer Science (LIACS), Leiden University*)

**CO-PROMOTERS**

Dr. Ir. R.J. Doll (*Leiden University*)

**DOCTORATE COMMITTEE**

Prof. Dr. A. F. Cohen

Prof. Dr. A. Brouwer (*Radboud University*)

Dr. M. Baratchi (*Leiden Institute of Advanced Computer Science (LIACS), Leiden University*)

Prof. Dr. M. Hoogendoorn (*Vrije Universiteit Amsterdam*)

**PART I – INTRODUCTION****CHAPTER 1**

Introduction — 9

**CHAPTER 2**

Machine learning techniques for developing remotely monitored central nervous system biomarkers using wearable sensors: a narrative literature review — 23

**PART II – CLASSIFICATION OF DIAGNOSIS****CHAPTER 3**

Objective monitoring of facioscapulohumeral dystrophy during clinical trials using a smartphone app and wearables: observational study — 89

**PART III – ESTIMATION OF SYMPTOM SEVERITY****CHAPTER 4**

Smartphone and wearable sensors for the estimation of facioscapulohumeral muscular dystrophy disease severity: cross-sectional study — 117

**CHAPTER 5**

A smartphone- and wearable-based biomarker for the estimation of unipolar depression severity — 145

**CHAPTER 6**

Development and technical validation of a smartphone-based pediatric cough detection algorithm — 179

**CHAPTER 7**

Development and technical validation of a smartphone-based cry detection algorithm — 199

**PART IV – DETECTION OF TREATMENT EFFECTS****CHAPTER 8**

Treatment detection and movement disorder society-unified Parkinson's Disease rating scale, part III estimation using finger tapping tasks — 225

**PART V – DISCUSSION****CHAPTER 9**

General discussion — 253

**APPENDICES**

Summary — 269

Nederlandse samenvatting — 283

中文摘要 — 297

List of publications — 306

Curriculum vitae — 309

Acknowledgements – Dankwoord – 致谢 — 311