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Development and expert-evaluation of FORENSICA-android application for estimating post-mortem interval

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Time of death

ABSTRACT Death registration is very important and has civil and legal impact on the deceased person and their family. Validity of a death certificate is influenced by the time accuracy of death estimation. Calculation of the post-mortem interval has a central role in the estimation of the time of death, especially for death cases in the community, without prior medical observation. This study aimed to develop a smartphone application for counting the estimated time of death based on android features, to help doctors establish a more accurate time of death and provide a learning facility for doctors and medical student. This action research consisted of 4 cycles: 1) Planning, 2) Action, 3) Observation, and 4) Reflection. The final result of this study is an android application named Forensica 3rd version. This application was developed in Bahasa Indonesia. This application has a menu for recording the patient identity, instructions for post-mortem changes examination, record examination results, time of death calculation and its interpretation. This 3rd version of the application is the latest version after undergoing two revisions. The Forensica application provides an easy way for doctors and medical students to establish the time of death estimation and it is user-friendly.

1. Introduction

Time of death estimation is an important part of forensic medicine. Although this issue is important, some doctors forget how to calculate it and get confused when facing a case of death in the community setting. The researchers tried to fix this problem by developing a smartphone application to guide the doctors in performing post-mortem examinations and calculating the results. It is important because the validity of a death certificate is also influenced by the accuracy of the time of death estimation. Post-mortem interval calculation has a central role in estimating the time of death, especially in the community setting.

By helping doctors to calculate the post-mortem interval faster, we hope that doctors can issue death certificates faster and ultimately help the family to have easier access to all of their rights. Use of technology, by developing a smartphone application, is chosen to help establish the time of death estimation faster. Also, the doctors can access the application anywhere and anytime they need.

We found only two studies that focused on the usage of the mobile phone for postmortem interval estimation, although the scope is different between the two. The first study[1] used a smart-phone with a special optical contraption in addition to estimate the postmortem interval by analyzing the cornea of the corpse. Another study[2] used the phone, mainly through the short messaging service (SMS), to build a reporting system in Pakistan. While this study

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focuses on the general reporting system, we also found that the reporting topic is forensic-related (neonatal, infant, and maternal death). Systematic reviews that are related to mobile-phone usage in the medical field mostly focused on other topics such as obesity treatment,[3] hypertension treatment,[4] mental disorders treatment[5] and health behavior changes.[6] The usage of mobile phone applications for postmortem interval estimation is yet to be found in the literature.

This study aimed to develop a smartphone android-based application to calculate the interval of death estimation, to help doctors to establish the time of death and also to provide a learning facility for doctors and medical students.

Figure 1. Action research.

2. Method

The method used is action research that includes four cycle of procedures such as planning, action, observation, and reflection. The flow chart is attached and must be fully and clearly done. The method was chosen to generate a shift in the understanding and contextualization of the role of academic professionals in both higher education and the larger environment.[7] These grounding concepts of medical doctors' experiences and problems in community create the backdrop for interpreting social reality and subsequently advising concrete actions to solve pertinent problems.[8] The action research involved all participants to contribute more in the research and solve the problems faced by their colleagues in social reality.[9]

2.1. Planning

This procedure was preceded by collecting criteria of post-mortem changes and constructing the formula for counting the estimation of the time of death.

2.2. Action

This procedure involved developing a smartphone application for time of death estimation calculation. The development is based on an android system, named Forensica 1st version. Peer review was done after this step, and the application was revised. The result of this action procedure is a revised version of the application that is named Forensica 2nd version.

2.3. Observation

This step in the procedure aimed to put the application into trial. A total of 12 forensic experts were involved from the Department of Forensic and Medicolegal FKKMK UGM. The sampling method was done by the total sampling method. All experts joined a group review and were invited to focus group discussions. All experts tried the smartphone application called Forensica 2nd version and gave evaluations about it on three aspects: system, user, and interaction aspects. To develop the questions, we adapted the USE questionnaire.[10] It consists of 13 questions with a 5-point Likert scale. We removed two questions about payment and security because this application is free and does not collect confidential data.

In addition, the experts have also conducted reviews related to the content of Forensica. The literature search was done after the review process. The references used are international references that have been agreed to be the reference sources. One was an agreement on the determination of livor mortis. Livor mortis persists more than 8 hours after death. This was previously debated because there was a difference in cut-off points (6 and 8 hours).

Table 1. Post-mortem interval based on post-mortem changes

No	Sign	Postmortem interval	Postmortem changes	Confounding factors
1	Livor mortis	30 minutes 8 hours	Start observed Settled	-Skin color -Oxygenation status -Status oxygenation -Hemolysis -Temperature -Decomposition -Movement of body position -Intoxication
2	Rigor mortis	2 hours 12 hours 24 hours	Start observed All muscles, maximum rigidity, settled Maximum rigidity starts to release	-Muscle mass -Surrounding temperature -Muscle activity before death -Disease or toxin which influence nerve and muscle activity. -Chronical illness that impacts muscle mass -Decomposition
3	Decomposition	1-3 days	Greenish on the abdominal wall observed	-Body size -Body size -Temperature -Humidity -Oxygen access -Cloths and cover -Embalming -Open or close environment -Immersed -Buried -Bacterial infection -Maggots infestation -Predator

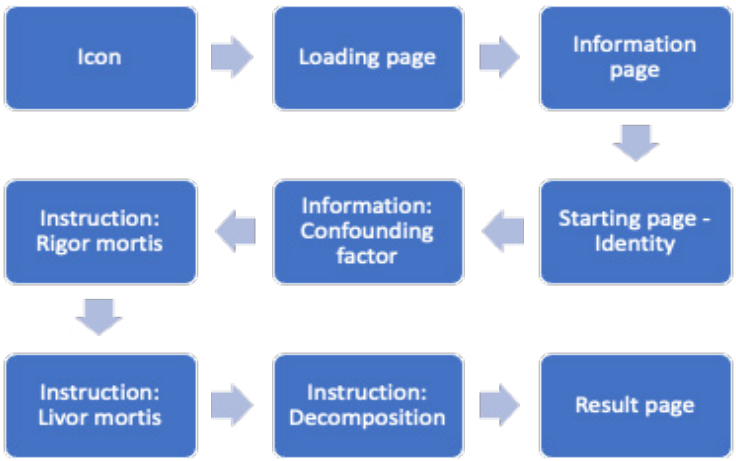

Figure 2. Forensica overall operational process.

2.4. Reflections

This step in the procedure revalidated the instruments. There were also pretest and post-tests to review the efficacy of the application. The data were analyzed by using Python (this includes pandas, numpy, pyplot, seaborn, and scipy modules) to find descriptive statistics, comparison between pretest and posttest, and generate the charts. We did data collection and cleaning prior to the analyses. The

Figure 3. The icon of FORENSICA application.

third revision was done next, and the result of this action research was named Forensica 3rd version. This study was approved by the Medical and Health Research Ethics Committee of the Faculty of Medicine, Public Health, and Nursing Universitas Gadjah Mada, Yogyakarta, Indonesia (Ref. No. KE/FK/0567/EC/2021).

3. Result

The results of this study are presented according to the four-cycle procedures which were performed in this study.

3.1.Planning

The planning step of this research was done by collecting criteria of post-mortem changes. These criteria then were used to construct the formula that would be used to calculate the time of death estimation. There are many methods in which someone can estimate the time of death, with distinct advantages and disadvantages. After a comprehensive literature study[11-30] was done, it was concluded that there are several criteria that can be used. Livor mortis, body temperature, rigor mortis, decomposition, mummification, and the biochemical process can be used as the criteria.

Body temperature was not used as criteria for this research due to its complex interaction with the environment. It can be used for a specific computational model, including the models for hypothermia and hyperthermia.[1,3] But for this specific application, it was deemed too varied. Another criteria that was not used is mummification. This is due to Indonesia's climate that has high humidity and warm temperatures, which do not support the process of mummification to occur and instead support decomposition to occur faster. Another of the criteria that is not used is the post-mortem biochemical process which is a relatively new approach that needs more practical effort to do.[32]

The researchers conclude that the remaining three criteria are used in this application: livor mortis, rigor mortis, and decomposition as presented below in Table 1.

3.2.Action

The next step is action. The action step was done by developing the android application named Forensica 1st version. After initial peer-review, the application was then revised into Forensica 2nd version. The application is shown below.

The icon for the application (Figure 3) was designed on the wall of the smart phone after installation. The operational process is started by clicking the icon. The user goes to the loading page that includes the title "Forensica" and the tagline "Easier learning, good understanding". Then it proceeds to the next pages, which are the information pages to better introduce the application being used by the users. The next page is the starting page in which the user is asked for the patient's name and their identity number. Then the next page shows information on confounding factors. The next pages are the instructions on doing rigor mortis, livor mortis, and decomposition examinations. The last page in the process is the results page.

3.3.Observation

The observation step of this study was done by putting the application into trial. Doctors were invited to a focus group discussion in which they tried the 2nd version of the application. The doctors agreed that the 2nd version was easily operated in three main aspects (system, user, and interaction aspect). There were 11 questions that were asked in Bahasa Indonesia using the Likert scale. The English translation is below each question.

Table 2. Observation result.

No	Question	Result
1	*Apakah tampilan antarmuka aplikasi FORENSICA mudah dikenali?* Is the interface of Forensica easy to recognise?	4.625
2	*Apakah aplikasi FORENSICA mudah dioperasikan?* Is Forensica easy to operate?	4.8125
3	*Apakah tampilan warna pada aplikasi FORENSICA nyaman dilihat dan tidak membosankan?* Is the color theme of the application easy on the eye?	4.25
4	*Apakah tampilan menu dalam aplikasi FORENSICA mudah dikenali?* Is the menu interface in the application easy to navigate?	4.5
5	*Apakah informasi dalam aplikasi FORENSICA mudah dicari?* Is the informations available on the application easy to search?	4.5625
6	*Apakah tulisan yang ada dalam aplikasi FORENSICA mudah dibaca?* Is the writing readable?	4.4375
7	*Apakah aplikasi FORENSICA mudah di-download?* Is the application easy to download?	4.625
8	*Apakah simbol, ikon, dan gambar dalam aplikasi FORENSICA mudah dipahami?* Are the symbols, icons, and pictures in the application easy to understand?	4.5625
9	*Apakah mudah mengakses informasi yang ditawarkan dalam aplikasi FORENSICA?* Is the information available on the application easy to access?	4.625
10	*Apakah fungsi yang ditawarkan sesuai dengan tujuan dalam aplikasi FORENSICA?* Is the function of the application in accordance with the goal?	4.625
11	*Apakah menu dalam aplikasi FORENSICA mudah diingat?* Is the menu on the application easy to remember?	4.625

(1 = "strongly disagree", 2 = "disagree", 3 = "in doubt", 4 = "agree", 5 = "strongly agree")

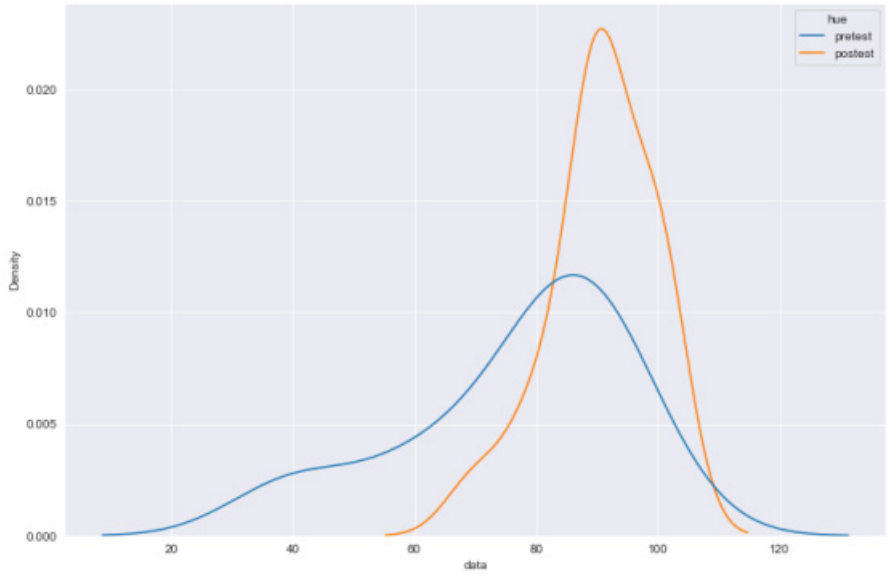

Figure 4. Kernel Density Estimate (KDE) plot showing difference of distributions between pretest results (shown in blue) and post-test results (shown in orange).

There were also suggestions on the application's layout, interface, and the availability of the application in the PlayStore. The first one was the layout of the confounding factors which were slightly confusing, so the developers rearranged the layout to be fully top-down. The second one was the chosen gray color

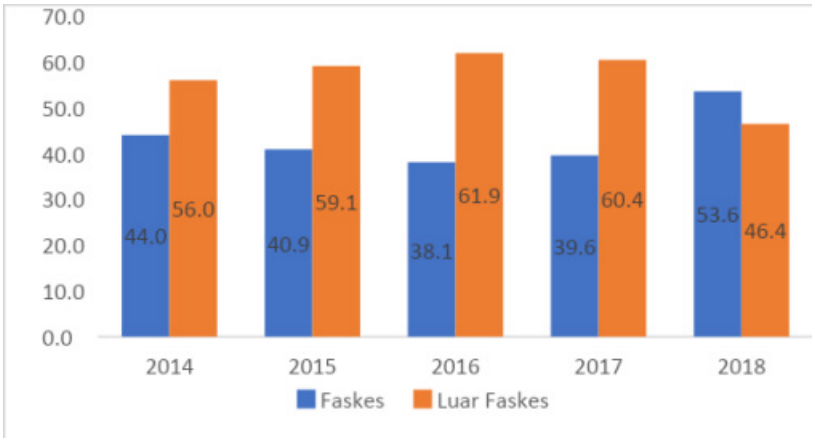

Figure 5. Place of death. Blue shows the intra health facilities mortality while the orange shows the mortality outside health facilities.

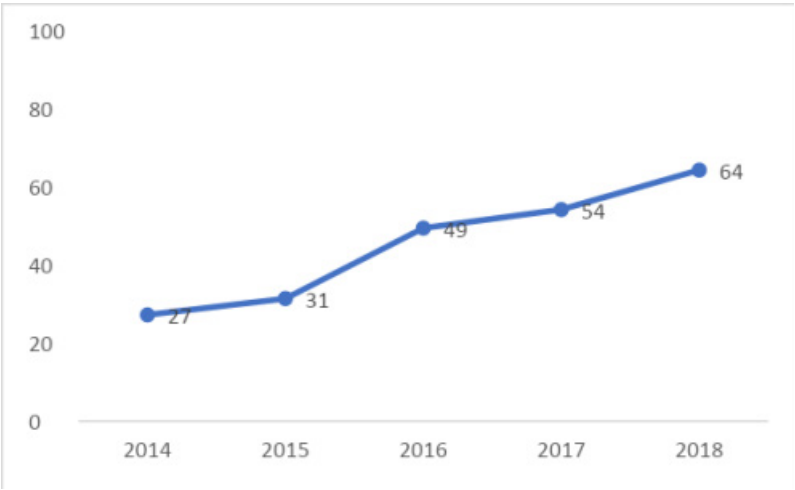

Figure 6. Death registration according to death certificate issued.

for the writing which was sometimes hard to read, then it was changed to black. The last one was that the application was not yet available on PlayStore, so it was uploaded after the research was done.

3.4. Reflections

In the last step of this research, a revalidation process was done to the instrument. Slight readjustment on the formula to adjust to the specific climate in Indonesia were done. We adjusted the formula of the time of death estimation based on the current literature that conforms with our setting. We also modified the application's display based on the responses in the questionnaires. Pre- and post-tests showed significant differences with a p-value of 0.011 (Mann-Whitney test). After the third and fourth step, the application was once again revised into Forensica 3rd version.

4. Discussion

The issuance of the death certificate is a document which plays many roles in the socio-economic area. It is mandatory to be issued in any death case. Legal and civil impacts of the death certificate will influence people's well-being, such as legacy, pension, insurance claim, banking business, testament of marriage, spouse's next marriage, and other important issues. The Health and Demographic Surveillance System

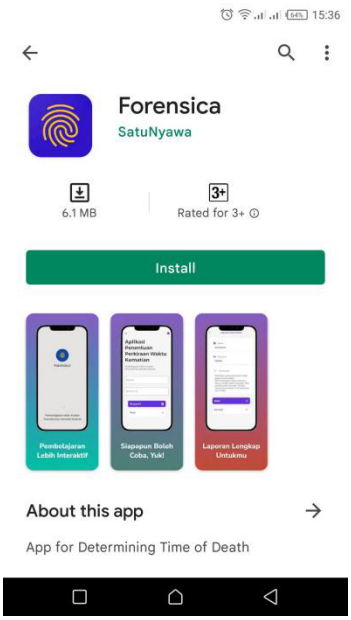

Figure 7. Forensics application in PlayStore.

(HDSS) data in Sleman 2016-2018 showed that death cases in community are more numerous than death cases intra health facilities (Figure 4).

HDSS Sleman data also show that not all death cases are registered and get death certificates. There is improvement in the amount of death cases being reported, although it is still below what is expected (Figure 5). According to the regulations, all death cases must be registered and get a death certificate. Included in a death certificate are data of identity, place of death, and time of death. Medical doctors have the duty to issue the death certificate after examination. Complicated subjects in the medical education program and the development of science in medical issues push medical doctors to become quick adapted learners. Medical doctors' responsibility leads them to improve their knowledge and skills, provide high standard service, and this includes the validity of the death certificate in each component.

The COVID-19 pandemic also plays an important role when regarding the death cases. Ever since the start of the pandemic, per 2nd of September 2021, there were 133,676 cases of death due to COVID-19 alone.[33] Some of them were treated in hospitals and some others were self-quarantined at home.

Per 7th of August 2021, there were 3,013 cases of death that occurred within the self-quarantined patients' community, specifically those who were quarantining outside hospitals.[34] The recent rise of COVID-19 self-quarantined patients death necessitates a faster and safer way to estimate the time of death.

Smartphone users in Indonesia are more than 100 billion in 2018.[35] Internet penetrations reach the same rate in 2018, with an average access for internet of 3.5 hours per day in Indonesia using smartphones.[36] Medical doctors are a part of that population. Doctors have the obligation to improve their knowledge and skills, and also have opportunity to use smartphones as a tool. Continuing medical education using android applications that is developed and dedicated to help doctors in their duty is a challenge for improving health services.

Smartphone application implementation in health settings are usually about health intervention. Implementations widely used include weight monitoring and calorie calculator, such as in the study conducted by Wang and colleagues.[37] Another implementation is for mental health treatment[38] and hypertension treatment.[39] One research studied an application for health behavior changes, encompassing different fields of interventions.[40] Smartphone applications used in the context of reporting and estimation of the time of death are rare in the literature. We found two researches that use mobile phone for estimation and reporting. One study is conducted in Pakistan, while not necessarily using a smartphone, it was using SMS via mobile phones to report death.[41] Another study resembles this study, that is using an application to estimate postmortem interval. Although the goal of the study is the same with this study, there are significant differences between the studies: the method used and the need (or lack of need) of additional contraptions.[42] The application uses images of the cornea to estimate the time of death. As images can vary between shots, especially using smartphone, the application is used in combination with a special contraption that provides lighting and thus minimizes the differences between shots.

All these facts add to the urgency of the

development of the Forensica application. By developing Forensica, death outside health facilities can be examined and estimated faster. This would improve the overall registered death number and ultimately give better services to the family by getting them the rights they deserve faster.

Based on this research, the Forensica application can be implemented in daily practice, which is proven by all items in the questionnaire getting more than 4 marks of the maximum 5-point Likert scale. The Forensica application is already available in PlayStore (Figure 7) and also recorded in Intellectual Property Right certificate no: EC00202183651. This study is limited by the fact that the experts involved come from only one center. For further studies, more experts from more diverse centers can be involved.

5. Conclusion

The Forensica application is a smartphone application based on the android system, developed for guiding doctors and medical students to examine post-mortem changes and calculate estimation of the time of death. The Forensica application provides an easy way for doctors and medical students to establish the time of death estimation and it is user friendly.

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Conflict of interests

There is no conflict of interest in this study.

References

1. Zheng JL, Huo DM, Wen HY, Shang QF, Sun WK, Xu ZT. Corneal-Smart Phone: A novel method to intelligently estimate postmortem interval. J Forensic Sci. 2021;66(1):356–64.
2. Durrani MIA, Qureshi NS, Ahmad N, Naz T, Amelio A. A Health Informatics Reporting System for Technology Illiterate Workforce Using Mobile Phone. Appl Clin Inform. 2019;10(2):348–57.
3. Wang Y, Xue H, Huang Y, Huang L, Zhang D. A Systematic Review of Application and Effectiveness of mHealth Interventions for Obesity. Adv Nutr. 2017;8(3):449–62.
4. Xu H, Long H. The Effect of Smartphone App–Based Interventions for Patients With Hypertension: Systematic Review and Meta-Analysis. JMIR mHealth uHealth. 2020 Oct 19;8(10):e21759.
5. Miralles I, Granell C, Díaz-Sanahuja L, Van Woensel W, Bretón-López J, Mira A, et al. Smartphone Apps for the Treatment of Mental Disorders: Systematic Review. JMIR mHealth uHealth. 2020 Apr 2;8(4):e14897.
6. McKay FH, Cheng C, Wright A, Shill J, Stephens H, Uccellini M. Evaluating mobile phone applications for health behaviour change: A systematic review. J Telemed Telecare. 2018;24(1):22–30.
7. Reason P, Bradbury H. The SAGE Handbook of Action Research [Internet]. 1 Oliver's Yard, 55 City Road, London England EC1Y 1SP United Kingdom: SAGE Publications Ltd; 2008. Available from: http://methods.sagepub.com/book/the-sage-handbook-of-action-research
8. Ibid.
9. Ibid.
10. Rahadi DR. Pengukuran Usability Sistem Menggunakan Use Questionnaire Pada Aplikasi Android. J Sist Inf. 2014;6:661–71.
11. Sauko P, Knight B. Knight's Forensic Pathology. 4th ed. New York: CRC Press; 2016.
12. Dimaio V, Dimaio D. Forensic Pathology. New York: CRC Press; 2001.
13. Krishan V. Forensic Medicine and Toxicology : Principles and Practice. 5th ed. Elsevier; 2005.
14. David D, Evan M, Emma L. Forensic Pathology : Principles and Practice. Elsevier; 2005.
15. Bardale R. Principles of Forensic Medicine and Toxicology. India: Jaypee; 2011.
16. Payne-James J, Byard R, Corey T, Henderson C. Encyclopedia Of Forensic And Legal Medicine. 1st ed. London: Academic Press; 2005.
17. Simpson KC. Simpson's Forensic Medicine. 13th ed. London: Hodder & Stoughton Ltd.; 2011.
18. Bohnert M, Weinmann W, Pollak S.

Spectrophotometric evaluation of postmortem lividity. Forensic Sci Int. 1999 Jan;99(2):149–58.

19. D'Souza D, Rajesh M, Harish S, Kiran J. Rigor mortis in an unusual position: Forensic considerations. Int J Appl Basic Med Res. 2011;1(2):120.
20. Gill JR, Marker E, Stajic M. Suicide by cyanide: 17 deaths. J Forensic Sci [Internet]. 2004 Jul;49(4):826–8.
21. Hayman J, Oxenham M. Supravital Reactions in the Estimation of the Time Since Death (TSD). In: Human Body Decomposition [Internet]. Elsevier; 2016. p. 1–12. Available from: https://linkinghub.elsevier.com/retrieve/pii/B9780128036914000017
22. Janaway RC, Percival SL, Wilson AS. Decomposition of Human Remains. In: Microbiology and Aging [Internet]. Totowa, NJ: Humana Press; 2009. p. 313–34. Available from: http://link.springer.com/10.1007/978-1-59745-327-1_14
23. Kobayashi M, Takatori T, Nakajima M, Sakurada K, Hatanaka K, Ikegaya H, et al. Onset of rigor mortis is earlier in red muscle than in white muscle. Int J Legal Me. 2000 Jun 16;113(4):240–3.
24. Kori S. Time since Death from Rigor Mortis: Forensic Prospective. J Forensic Sci Crim Investig. 2018 Jul 5;9(5).
25. Ranjan SK, Kumari P, Kumar A, Kumar S, Kumari B. Observational Study to Estimate Time since Death on the Basis of Post-Mortem Staining, Rigor Mortis, Ocular and Putrefaction Changes in Dead Body. Int J Health Sci (Qassim). 2019;9(10):100–4.
26. Ruas F, Mendonça MC, Real FC, Vieira DN, Teixeira HM. Carbon monoxide poisoning as a cause of death and differential diagnosis in the forensic practice: A retrospective study, 2000–2010. J Forensic Leg Med. 2014 May;24:1–6.
27. Schotsmans EMJ, Van de Voorde W, Forbes SL. TSD estimation in the advanced stages of decomposition. In: Estimation of the Time since Death [Internet]. Elsevier; 2020. p. 81–107. Available from: https://linkinghub.elsevier.com/retrieve/pii/B9780128157312000054
28. Shedge R, Krishan K, Warrier V, Kanchan T. Postmortem Changes. Statspearl [Internet]. 2021; Available from: http://www.ncbi.nlm.nih.gov/books/NBK539741/
29. Steward O, Balice-Gordon R. Rigor or Mortis: Best Practices for Preclinical Research in Neuroscience. Neuron. 2014 Nov;84(3):572–81.
30. Sugatha M, Ramana V. Assessment of Time Since Death using Forensic Autopsies based on the Presence of Rigor Mortis– A Cross-Sectional Study. Int J Contemp Med Res [IJCMR]. 2019 Apr;6(4).
31. Schweitzer W, Thali MJ. Computationally approximated solution for the equation for Henssge's time of death estimation. BMC Med Inform Decis Mak. 2019 Dec 28;19(1):201.
32. Zissler A, Stoiber W, Steinbacher P, Geissenberger J, Monticelli FC, Pittner S. Postmortem Protein Degradation as a Tool to Estimate the PMI: A Systematic Review. Diagnostics. 2020 Nov 26;10(12):1014.
33. Laporcovid19.org. Statistik Kematian Isolasi Mandiri dan Di Luar RS [Internet]. 2021 [cited 2021 Sep 2]. Available from: https://laporcovid19.org/data/kematian-isoman
34. Covid19.go.id. Peta Sebaran | Covid19.go.id [Internet]. 2021 [cited 2021 Sep 2]. Available from: https://covid19.go.id/peta-sebaran
35. Milward S. Indonesia to be world's fourth-largest smartphone market by 2018 [Internet]. Tech in Asia. 2014 [cited 2020 Dec 23]. Available from: https://www.techinasia.com/indonesia-worlds-fourth-largest-smartphone-2018-surpass-100-million-users
36. Das K, Gryseels M, Sudhir P, Tan K. Unlocking Indonesia's digital opportunity [Internet]. McKinsey Indonesia Office. 2016. Available from: https://www.mckinsey.com/~/media/McKinsey/
37. Wang Y, Xue H, Huang Y, Huang L, Zhang D. A Systematic Review of Application and Effectiveness of mHealth Interventions for Obesity. Adv Nutr. 2017;8(3):449–62.
38. Miralles I, Granell C, Díaz-Sanahuja L, Van Woensel W, Bretón-López J, Mira A, et al. Smartphone Apps for the Treatment of Mental Disorders: Systematic Review. JMIR mHealth

uHealth. 2020 Apr 2;8(4):e14897.

39. Ibid.
40. Xu H, Long H. The Effect of Smartphone App–Based Interventions for Patients With Hypertension: Systematic Review and Meta-Analysis. JMIR mHealth uHealth. 2020 Oct 19;8(10):e21759.
41. McKay FH, Cheng C, Wright A, Shill J, Stephens H, Uccellini M. Evaluating mobile phone applications for health behaviour change: A systematic review. J Telemed Telecare. 2018;24(1):22–30.
42. Durrani MIA, Qureshi NS, Ahmad N, Naz T, Amelio A. A Health Informatics Reporting System for Technology Illiterate Workforce Using Mobile Phone. Appl Clin Inform. 2019;10(2):348–57.