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The potential impact of wearables on physical activity guidelines and interventions: opportunities and challenges

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914 words, 8 references, 1 figure

Hundreds of millions of people own wearable devices capable of tracking their movement patterns[1]. Accelerometers are also increasingly the preferred tool to measure physical activity in research studies[2]. However, national and international physical activity guidelines, which recommend adults undertake at least 150-300 minutes of moderate intensity (MPA) or 75-150 minutes of vigorous intensity physical activity (VPA) per week, remain largely based on epidemiological studies in which physical activity was assessed using self-reported questionnaires. It is now known that such self-report measures generally overestimate moderate-to-vigorous physical activity (MVPA), are unlikely to accurately measure light intensity physical activity, and cannot capture very short bouts of incidental activity of any intensity[3]. These limitations impede the development of guidelines that reflect the true dose-response relationship between physical activity and health.

Recent prospective studies using wearable devices have started to transform our understanding of the association between physical activity and health outcomes. These suggest that the dose-response relationship between physical activity and health is steeper than self-report data suggest, with substantially smaller doses of device-measured MVPA (~40-80 min/week) associated with benefits similar to those from achieving the currently recommended levels (based on self-report), and an even greater benefit of being highly active than previously appreciated from self-reported data[4,5]. Such data have also demonstrated that just 3-4 min/day of device-measured intermittent VPA is associated with 30-40% lower risk of all-cause and cardiovascular disease mortality, even in people who report no leisure-time physical activity[6], and show benefits of engaging in light intensity activity, although minute-for-minute these are substantially smaller than engaging in MVPA[4,5]. Thus, current physical activity guidelines largely reflect the dose-response relationship between *perceived* – rather than *actual* – levels of physical activity and health outcomes, and the amount of device-measured physical activity needed for health benefits appears to be smaller than previously thought. This new evidence from wearable devices provides important opportunities and challenges for the development of future physical activity guidelines and for interventions to encourage physical activity.

Development of physical activity intervention approaches: Mining of physical activity data from wearables has facilitated, and will continue to facilitate, new insights into how both dose and pattern of physical activity affect health outcomes, for example demonstrating potential benefits of micro-patterns of VPA[6], and of breaking up periods of continuous sedentary time[7]. These observations provide opportunities to test the efficacy and long-term effectiveness of novel device-monitored intervention approaches, expanding the range of physical activity behaviour change options available, particularly for the most inactive who stand to gain most from increased activity even at low and/or intermittent levels.

Research-grade vs consumer wearables: Most of the evidence about the dose-response relationships between activity behaviours and health outcomes has come from studies using research-grade accelerometers. However, individuals monitoring their own activity will typically use consumer-devices with proprietary algorithms that do not necessarily measure activity in the same way or with the same accuracy. For example, it is unclear how a metric such as 'very active' minutes on a consumer-device relates to definitions of MPA and VPA used in research. Greater understanding is needed of how activity metrics from consumer-based wearables: 1) relate to outputs from research-grade devices, and other models of consumer-device; and 2) relate to health outcomes. The recent data from the *All of Us* Research Program, demonstrating an association between step counts from individuals' personal wearable devices (Fitbit) and health outcomes, is an important first step in this direction[8], but further studies with a more comprehensive range of activity metrics, in more diverse populations (including in historically underrepresented and marginalised groups), and with a wider range of devices are needed. In addition, there is potential to use consumer-devices for long-term monitoring to provide insights into within-individual variability in physical activity levels and trends in activity patterns over time. However, using data from individuals' own devices presents challenges around data ownership and privacy, representativeness of the populations studied (users are likely to skew towards the more affluent and health-conscious), and alignment of activity metrics between different devices.

Device-based activity monitoring: Self-report and wearables capture different constructs: questionnaires capture continuous blocks of time during which bouts of activity occur whereas devices capture actual physical activity bouts of any duration including those that occur intermittently (Figure 1). It is therefore important that the methods used to generate the guidelines align with those used to monitor adherence. Using self-report to monitor adherence to a new device-based guideline would likely lead to overestimation of MVPA and underestimation of intermittent VPA and light activity. Thus, if guidelines were changed to reflect device-based data, monitoring of physical activity would also need to be performed by devices. The converse is true with respect to understanding adherence to existing guidelines. It will be important to ensure that changes to both guidelines and adherence monitoring methods are made through an equity lens, which can be iteratively re-assessed as device costs decrease, mobile accessibility increases, and scalability and reach improve. As it unlikely that devices will become universally available in the foreseeable future, particularly in low- and middle-income countries, additional innovative work is needed to understand how device-measured and self-reported physical activity can be aligned in cohort and monitoring studies.

In summary, wearable devices are already transforming how we research, prescribe and monitor physical activity. It is more important than ever for industry, academia, and public health communities to work together to maximise the considerable potential that wearables offer to advance and translate our understanding of both how activity behaviours influence health and how to improve interventional approaches to increase physical activity.

Competing Interests: JMRG is Deputy Editor for Physical Activity and Population Health at BJSM. AD is supported by the Wellcome Trust [223100/Z/21/Z], Novo Nordisk, Swiss Re, the British Heart Foundation Centre of Research Excellence (grant number RE/18/3/34214). ES is funded by an Australian National Health and Medical Research Council (NHMRC) Leadership level 2 Investigator Grant (APP 1194510).

Contributorship: This work was originally conceived by JMRG, TJAC and ES, and all authors made substantial contributions to refining and shaping the initial ideas. JMRG wrote the first draft; all authors contributed to revisions in subsequent drafts. All authors approved the final version and are accountable for all aspects of the work.

Acknowledgments: none

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Ethical approval: not applicable

Data sharing: not applicable

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Figure Legend

Physical activity captured by self-report questionnaire (top panels) and wearable device (bottom panels) in 2 different scenarios: a session in the gym (left) and during intermittent activities of daily living (right panel). Questionnaires overestimate physical activity in the former but underestimate physical activity in the latter.

N.B. Simplified examples to illustrate the central point. VPA: vigorous physical activity.

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The author team includes six men and three women, who are all from high-income countries: United Kingdom, United States, Norway and Australia. One author is mixed-race, the others are white. The research cited in this editorial is largely from high-income countries which reflects the available data on device-based physical activity measurement and health outcomes. The need to ensure that changes to both guidelines and adherence monitoring methods are made through an equity lens, and the need for studies in more diverse populations are mentioned as important considerations in the editorial. We acknowledge that more data are required from diverse populations, particularly in low-and-middle income countries, and hope that this editorial can help highlight this need.

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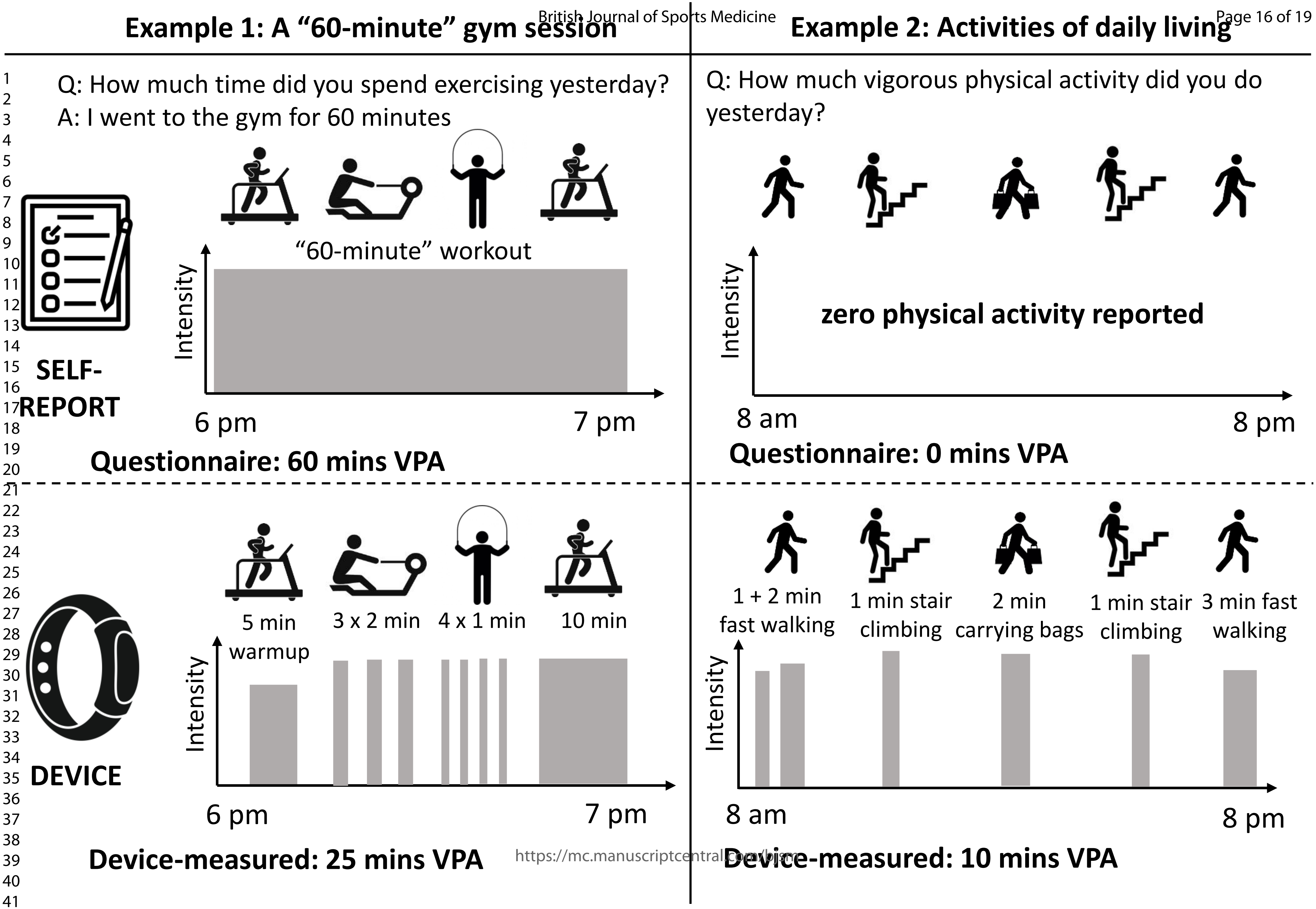
Example 1: A "60-minute" gym session
Example 2: Activities of daily living
Q: How much time did you spend exercising yesterday?
A: I went to the gym for 60 minutes
"60-minute" workout
Intensity
6 pm
7 pm
SELF-REPORT
Questionnaire: 60 mins VPA
Q: How much vigorous physical activity did you do yesterday?
zero physical activity reported
Intensity
8 am
8 pm
Questionnaire: 0 mins VPA
5 min warmup
3 x 2 min
4 x 1 min
10 min
Intensity
6 pm
7 pm
DEVICE
Device-measured: 25 mins VPA
1 + 2 min fast walking
1 min stair climbing
2 min carrying bags
1 min stair climbing
3 min fast walking
Intensity
8 am
8 pm
Device-measured: 10 mins VPA

Dear Dr Kemp and reviewers

We would like to thank you for your comprehensive and thoughtful evaluation of this editorial. We have carefully considered all of the comments and have revised our manuscript accordingly. Our point-by-point responses are highlighted in red below and specific changes to the manuscript are highlighted in yellow. To fully address the reviewers' comments, the word count has increased slightly to 914 words. We hope that this is acceptable. Thank you for considering this work for publication in BJSM and we look forward to hearing your decision this revised version in due course.

Kind regards

Jason Gill on behalf of all authors

Formatting Amendments (where applicable):

Please make sure the following statements are included in the main document file, which should match the details given in the submission pages:
Competing interests
Contributorship
Acknowledgements
Funding and grant/award info, name and number Ethical approval information, name and number
Data sharing statement If there is no information to add, please include: none or not applicable.

Authors' response: Thank you. We have made these changes.

The figure should be supplied in 300dpi TIFF, JPEG,EPS or PDF format.

Authors' response: Thank you. We have converted the figure to pdf.

Reviewer(s)' Comments to Author (if any):

Reviewer: 1

Comments to the Author
Thank you for taking the time to put together this interesting Editorial that presents a perspective of current and future interplay between physical activity guidelines and the use of wearable devices. It was enjoyable to read. I am sure it will be of interest to the BJSM readership and generate some conversation and debate in this arena

Authors' response: Thank you for your kind comments.

Page 2 – paragraph one (starting line 35) and paragraph 2 (starting line 46) Paragraph one presents MPA and VPA guidelines as separate entities. The doses associated with device-measured recommendations in paragraph 2 are presented as a single MVPA figure. Consistency between the two paragraphs would be helpful to facilitate an understanding of the impact on guidelines/expectations.

Authors' response: Thank you for this thoughtful comment and we appreciate your concern. We presented in this way to represent the way that physical activity guidelines are expressed in paragraph one (MPA and VPA considered separately) and how the device-measured data are reported in the epidemiological studies cited in paragraph two (i.e. as MVPA). Thus, it is not possible to use the exact same terminology in both paragraphs while also being accurate in what we say. To make things clearer we have removed the second mention of MVPA on line 51. We hope this satisfies the reviewer's concern.

Device-based activity monitoring (starting line 62) How adaptable commercial device outputs are to population monitoring of guideline adherence is also of relevance here. Few commercial devices present outputs in the format of "MPA" and "VPA". In the same way that these definitions are often unhelpful to a public unclear about this terminology, the output of commercial devices (such as number of 'very active' minutes) can be difficult to correlate to research defined MPA/VPA cut points.

Author response: Thank you for this very helpful comment. We agree. In order to respond to all the reviewer comments while retaining a good logical flow of the points made, we have moved the order of the three paragraphs describing the opportunities and challenges that wearables provide, so we now first discuss development of physical activity intervention approaches, then research-grade vs consumer wearables, and finally device-based monitoring.

In the revised manuscript, we have added a new sentence in the section on research grade vs consumer wearables (lines 76-77) stating:

"For example, it is unclear how a metric such as 'very active' minutes on a consumer-device relates to definitions of MPA and VPA used in research."

Page 3 "Research-grade vs consumer wearables"
Line 89/90 – In addition to the relationship between commercial and research grade devices, the relationship between different commercial devices (with variable algorithms) is also something that requires better understanding if they are going to be used to underpin guidelines and monitor adherence.
The least complex algorithms (e.g. step count) are established as having the least variability across the range of commercial devices and research grade devices. We know that studies using a 'more comprehensive range of metrics' will, by their nature, reveal greater variability.

Author response: Thank you. We have expanded our point about greater understanding being needed of how activity metrics from consumer-based wearables related to outputs from research-grade devices to also include how they relate to outputs from other models of consumer device (line 79). We agree that studies with a more comprehensive range of metrics will reveal greater variability between devices. However other metrics than steps captured from consumer-wearables, particularly those which contain an intensity component, may have a different (potentially stronger) relationship with health outcomes than simply measuring steps which provide a measure of total activity independent of intensity. This is why we highlighted this as a research need here.

Figure 1
I understand that you are trying to simplify here to make a point, but it doesn't quite hold together.

I am assuming that the 5 min MPA (Example 1, device measured) correlates with the 5 minute warm-up, however in example 2, brisk walking, or walking carrying bags are classed as VPA.
Perhaps consider taking moderate and vigorous out of the equation (for both examples) and using the figure just to demonstrate the concept of potential differences between self-report and device measured PA data?

Author response: Thank you. We have now termed the warmup as VPA and have the total device-measured activity as 25 mins VPA.

Example 2 – the questionnaire and device measured sections are showing 2 different things. The questionnaire asks for 'continuous activity', for which the answer is zero – the device example is showing cumulative activity (the answer would still be zero in regard to 10 mins continuous activity). To be comparable, the question needs to be about cumulative activity. The same illustrations would work as it demonstrates the point that people forget about incidental activity undertaken.

Author response: Thank you. We have now removed mention of continuous activity in the question.

Reviewer: 2

Comments to the Author
Thank you for the opportunity to review this editorial about the use of wearable physical activity monitors. I believe the authors use the available word count well to explore their topic. I did not identify and spelling or grammar errors and think the writing is presented in a logical sequence.
I only have one small comment to slightly improve the clarity of your supporting Figure: I would recommend reversing the order of the time provided by the device to read "5 min MPA + 20 mins VPA" as this is the order the activity would be completed in your illustration. The formatting may have shrunk the image at my end but the lines seem to cross over with some of the bold titles.

Authors' response: Thank you for your kind comments. In response to your comment and the comment from Reviewer 1, we have now revised the Figure so that the warm-up is classified as VPA to increase consistency with Example 2, so we now have the total device-measured activity as 25 mins VPA.

Reviewer: 3

Comments to the Author
I'd like to commend the authors on an excellent, important and clearly written editorial. I offer the following thoughts to consider:

Authors' response: Thank you for your kind comments.

One aspect not touched upon here is privacy. Many (understandably) don't want data to be accessed by third party servers in other countries. The word 'surveillance' can have negative connotations. The question becomes, 'who owns the data'? Could you comment?

Authors' response: Thank you. This is a very important point. We have now added further text to the consumer wearables paragraph to highlight that important challenges remain in relation to consumer devices with respect to data ownership and privacy (as well as representativeness, and alignment of metrics between devices) (lines 84-89). We have also replaced the term surveillance with monitoring (line 97 and 104).

While objective data via accelerometry may be more accurate at capturing 'true' physical activity levels, I also wonder about the accuracy in research given the length of time that participants may wear the device and if this changes over time (ie the novelty wears off) – could you comment / reference anything specific to sustainability/long-term results?

Authors' response: Thank you. This is an interesting point. We feel that there are two issues here. Firstly, using devices to monitor physical activity. Here we don't know how long people would be prepared to wear devices for, which is likely to depend on whether data are being captured from their own consumer-device or a research-grade device supplied by researchers. The evidence (at least from the All of Us Research Program) is that a selected group of people are prepared to provide data from their own devices for several years. The second issue relates to how long people are prepared to engage with and use their device as a self-monitoring tool to support them in increasing their physical activity level. This is more uncertain. We have made an addition to line 67 to state that studies are needed to test the long-term effectiveness of novel device-monitored intervention approaches.

Very glad to see mention of equity– what about those who will never be able to afford even simple wearables? Wouldn't a change in guidelines, even if concurrent, potentially further deter those who can't afford to access the "right" (eg relatively wealthy person) guidelines?

Authors' response: Thank you. This is a very important point and is why we have emphasised that any changes to guidelines and monitoring would need to be made through as equity lens. Any changes to guidelines would need to be made with sensitivity to the concern that many, particularly in LMIC countries, will never be able to access a wearable device. This is why we have also emphasised the need for concurrent measurements with devices and self-report in surveillance and cohort studies to better understand how align self-report and device-based data.

It may also be of value to mention that a first step is to ensure research be undertaken in historically underrepresented / marginalized groups given the cost of these wearables – or do we have this data already?

Authors' response: Thank you. We have now mentioned the need for further research in historically underrepresented and marginalised groups on line 83.

Thanks -an enjoyable read.