

A Social Network Analysis of the Financial Links Backing Health and Fitness Apps

Quinn Grundy, RN, PhD, Fabian Held, PhD, and Lisa Bero, PhD

Objectives. To identify the major stakeholders in mobile health app development and to describe their financial relationships using social network analysis.

Methods. We conducted a structured content analysis of a purposive sample of prominent health and fitness apps available in November 2015 in the United States, Canada, and Australia. We conducted a social network analysis of apps' developers, investors, other funding sources, and content advisors to describe the financial relationships underpinning health app development.

Results. Prominent health and fitness apps are largely developed by private companies based in North America, with an average of 4.7 (SD = 5.5) financial relations, including founders, external investors, acquiring companies, and commercial partnerships. Network analysis revealed a core of 41 sampled apps connected to 415 other entities by 466 financial relations. This core largely comprised apps published by major technology, pharmaceutical, and fashion corporations. About one third of apps named advisors, many of whom had commercial affiliations.

Conclusions. Public health needs to extend its scrutiny and advocacy beyond the health messages contained within apps to understanding commercial influences on health and, when necessary, challenging them. (*Am J Public Health.* 2017;107:1783–1788. doi: 10.2105/AJPH.2017.303995)



See also Freudenberg, p. 1694; Millington, p. 1696; and Galea and Vaughan, p. 1703.

There are more than 100 000 mobile health applications (apps) commercially available, with market revenues projected to grow to US\$26 billion by 2017.¹ In 2015, smartphone users downloaded health apps more than 3 billion times.² Public health professionals are thus interested in the potential for apps to serve as vehicles for widespread, tailored, and accessible health promotion.^{3–6}

However, there has been little research into the role of commercial interest in mobile health⁷ or financial conflicts of interest that could bias app content.⁸ There are more than 45 000 health app developers, a population increasingly composed of large companies, with 17% classified as large corporations with over 5000 employees.² Researchers, however, have largely focused on the scientific accuracy of apps or the number and nature of app functions.^{7,9}

Public health researchers pioneered the study of corporate influences on health,

developing theoretical, methodological, and practical tools to identify and analyze the health impact of corporate activities.^{10–12} Globally, corporations are the dominant economic and social institution, with unprecedented capacity to shape lifestyles, social systems, and public policies.^{11,13,14} Studying corporations across industries, researchers have identified common activities that have tremendous influence on population health, including advertising, public relations, lobbying, campaign contributions, litigation, sponsorship of scientific research, and illegal activities.¹⁰ Researchers have applied this approach to the tobacco, pharmaceutical, food and beverage, automobile, gun, and alcohol

industries.^{10,15} To date, however, public health researchers have largely treated the technology industry as neutral, despite its direct entry into the field of health, characterizing its products as “unprecedented,” “disruptive,” and “revolutionary” solutions. Social researchers, by contrast, term this view “techno-utopian.”¹⁶

This optimism is generated by apps' ability to support self-management of health in the hopes of reducing health care costs and system burden.¹⁶ Individuals are encouraged to collect data about their health and to use this information to modify their lifestyles, which mobile health present as amenable to change, particularly with the aid of these technologies.^{17,18} However, critical public health researchers have suggested that this individualized approach may in fact reify existing health inequities, drawing attention away from the social determinants of health.^{13,18,19} For example, mobile health assumes access to digital technologies, health literacy, and the ability to effect lifestyle changes, which could leave individuals who are not able to self-manage their health open to discrimination or exclusion.^{13,17} Furthermore, the growing commercialization of consumers' data and the use of health apps for promotional purposes²⁰ may be used to target individuals to encourage further consumption, as in the case of tracking exercise,¹⁹ or to discriminate in relation to employment, housing, or insurance.¹³

Given the reach of smartphones, the growing demand for health apps, and the dominance of corporate actors, we need to understand the role of commercial entities in the development, funding, marketing,

ABOUT THE AUTHORS

Quinn Grundy and Lisa Bero are with the Faculty of Pharmacy and Fabian Held is with the Faculty of Science, the Charles Perkins Centre, The University of Sydney, Sydney, Australia.

Correspondence should be sent to Quinn Grundy, Postdoctoral Research Associate, D17, Level 6, The Hub, Charles Perkins Centre, The University of Sydney, Sydney, NSW, Australia, 2006 (e-mail: quinn.grundy@sydney.edu.au). Reprints can be ordered at <http://www.ajph.org> by clicking the “Reprints” link.

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dissemination, and regulation of health apps and what this means for population health. Part of researchers' silence about the commercial stakeholders in mobile health may be a result of the difficulty of identifying who is involved. App authorship and sponsorship are rarely transparent, making it difficult for consumers to detect bias, find an accountable party, or assess the trustworthiness of the app.⁷ Thus, we sought to identify the major stakeholders in mobile health app development and to describe their financial relationships using social network analysis.

METHODS

We conducted a structured content analysis of a purposive sample of health and fitness apps available in November 2015 in the United States, Canada, and Australia. We conducted a social network analysis of apps' developers, investors, other funding sources, and content advisors to describe the financial relationships underpinning health app development.

Sampling

App stores differ by country; their search algorithms are proprietary, personalized, and localized, and the population of apps changes rapidly.⁹ Thus, we triangulated 2 strategies to sample apps that received wide attention in terms of number of downloads, "top" rankings, and stakeholder attention: (1) an app store "crawling" program and (2) purposive sampling of apps in the media. These strategies allowed us to sample apps that are well established and up-and-coming so as to capture the dynamic nature of app development.

First, we systematically sampled apps on a weekly basis from the health and fitness store categories in the US, Canadian, and Australian iTunes and Google Play app stores using a crawling program that interacted directly with the stores' application programming interfaces.²¹ The program extracted the metadata on the 100 top-ranked apps as determined by the respective app stores. We included 441 apps that were ranked in the top 100 in at least 1 country store for 3 consecutive weeks in November 2015.

Second, we generated an additional purposive sample of 50 mobile health apps that had not yet achieved a top-100 ranking, but received coverage in mainstream media, industry newsletters (e.g., *MobiHealth News*, *RockHealth Weekly*), and social media in November 2015.

Two researchers independently screened the sample of 491 apps for inclusion and duplicates, defined as apps sharing at least 2 of the following: app name, developer, store description, linked Web site, logo, and app screenshots. The inclusion criteria were as follows: explicitly pertains to a medical (e.g., diabetes) or health condition (e.g., obesity), health risk factor (e.g., smoking), or health behavior (e.g., walking) and provides guidance or a recommendation (e.g., a workout program), tracks or records personal data, or makes a health claim (e.g., reduces anxiety).

Data Sources and Collection

We created an a priori coding instrument in REDCap²² based on a systematic review of methods for app content analysis.⁹ The instrument comprised 4 domains: app characteristics, partnerships, developer and funding characteristics, and privacy features. We piloted and modified the instrument and then tested it for reliability. The average percentage agreement of survey items was 94% for a random sample of 70 apps. A single rater coded the remaining apps in the sample ($n = 227$), and a second coder independently extracted data on partnerships and developer and funding characteristics. The authors resolved discrepancies through discussion until consensus was reached.

We gathered data between December 12, 2015, and April 1, 2016, from store descriptions, linked Web sites, Google searches, and public funding databases. Google Play was the default source when an app was available in both Google Play and iTunes app stores. We defined a "developer" as the entity that owned the app, although freelance app designers may have been listed as the "seller" in the store. We defined and subclassified reported "partnerships" as commercial "partners," content "advisors," or "sponsors." We further classified the "advisors" as "scientific" if the individual had a relevant PhD or health professional license and "non-

scientific" if the partner did not. We searched Crunchbase, a database of company profiles, for each developer to extract data on founders, investors, quantity of funding received, and acquisition or initial public offering (IPO) status.

Data Analysis

App and developer names frequently differed between platforms. Through a 2-stage process, we identified different instances of the same app or developer, first by automatically identifying similar names using approximate string matching²³ and then through cross-checking results manually to expand groups with common financial ownership. We then grouped apps into "families" on the basis of common ownership for the purpose of network analysis, using the same process. For example, the developer "Under Armour Inc" included the developers "MyFitnessPal" and "Endomondo," which it had acquired, and the app family "Under Armour" included all sampled apps published by Under Armour and its acquisitions.

We conducted descriptive analyses of app, developer, and funding characteristics in Excel (Microsoft, Redmond, WA). We conducted a network analysis of financial relations in R²⁴ using the *igraph* (1.0.1) library for network analysis and *gephi* (0.9.1) for visualization.

We describe 2 different networks. The financial network included developers, company founders, investors, sponsors (e.g., granting agencies), acquiring companies, and commercial partnerships. We considered content advisors to be a form of financial relationship, but we analyzed their connections separately. In most cases, however, developers did not disclose whether advisors received compensation.

RESULTS

After we eliminated duplicates and screened for eligibility, the sample included 297 unique apps. The majority ($n = 265$; 89%) had been sampled using the crawling program and the rest ($n = 32$; 11%) from media sources. App characteristics are summarized in Table 1.

TABLE 1—Characteristics of Sampled Health and Fitness Apps (n = 297): United States, Canada, and Australia; November 2015

Characteristic	No. of Apps (%)
Store availability	
Both Google Play and iTunes	202 (68.0)
iTunes only	52 (17.5)
Google Play only	39 (13.1)
Not in store	1 (0.3)
Cost	
Free to download	172 (57.9)
Paid	124 (41.7)
Offers in-app purchases	103 (34.6)
App focus	
Fitness workouts	86 (29.0)
GPS tracker/pedometer	45 (15.2)
Weight loss	37 (12.5)
Reproductive health	32 (10.8)
Diet/nutrition	22 (7.4)
Mental health	16 (5.4)
Sleep	14 (4.7)
Multifocus	11 (3.7)
Alternative health	10 (3.4)
Heart rate monitor	6 (2.0)
Hydration	6 (2.0)
Smoking cessation	4 (1.3)
Gym membership	3 (1.0)
Health information	3 (1.0)
Cancer	2 (0.7)

Note. GPS = global positioning system.

Developer and Funding Characteristics

The 297 apps were published by 231 unique developers. The majority of developers (n = 145; 63%) were privately held companies, and 54 (23%) were individuals. Twenty-five (11%) were publicly traded corporations or their subsidiaries. Only 7 developers (3%) were government, not-for-profit, or research organizations.

Most developers (200 of 231; 87%) reported their location; 119 of these (60%) were based in North America, 47 (24%) in Europe, and 20 (10%) in Australia. Most of the 231 developers sold or offered more than 1 app (n = 167; 72%), and 30 (13%) sold an associated wearable or device.

Of the 231 unique developers, 62 (27%) had some publicly available investment information (Figure A, available as a

supplement to the online version of this article at <http://www.ajph.org>). This included attracting venture capital (orange), acquisition by another company (green), making an IPO (purple), or a combination of these activities (signified by arrows). There was a large degree of variation: of the 50 developers attracting external funding, the median developer attracted US \$10.9 million in funding (median absolute deviation [MAD] = US \$14.4 million) from 5 investors (MAD = 4.4) over 3 funding rounds (MAD = 2.2). The median IPO raised US \$120.7 million, and the average acquisition was US \$150 million.

Twenty-two of the 231 unique developers (10%) had been acquired by another company, as early as 2001 (Baby Centre, LLC, by Johnson and Johnson) and as late as 2016 (Rise Labs Inc by One Medical Group). A number of acquiring companies were fashion related, including Under Armour, Fossil, and Adidas. Fourteen of the 231 unique developers made an IPO (6%), as early as 1978 (Pfizer Inc) and as late as 2015 (Fitbit Inc).

Financial Network

We grouped the 297 sampled apps into 222 app “families,” which shared a developer or an acquiring company. For the purposes of social network analysis, apps within a family shared financial ties and content advisors.

Financial ties. The network of financial relations contained 177 separate components, which included app families and their developers, founders, investors, sponsors, and all the financial ties among these entities (Figure B, available as a supplement to the online version of this article at <http://www.ajph.org>). Many apps were surrounded by their own distinct set of founders, funders, and developers. However, we identified 1 large, central component that connected 41 sampled apps with 415 other entities by 466 financial relations. This indicates that although sparsely connected, about 18% (41 of 222) of the app families had financial ties in common with other prominent health and fitness apps. Outside of this component, there were only 5 other cases in which 2 sampled apps shared overlapping financial relations. Overall, the network of financial relations was very sparse compared with similar networks,²⁵ with an overall density of 0.0007 and a density of

0.0022 in the central component, meaning that only a small fraction of possible relations among these entities actually occurred.

The connected central component was largely composed of app families published by major technology corporations (Google Inc; Samsung Group; Sony Corporation); companies that manufacture wearables (FitBit, Misfit/Fossil Group, Jawbone), smart devices and clothing (Skulpt, Lumo Body Tech, Athos), sports apparel (Under Armour), or pharmaceuticals (Johnson and Johnson); and companies that provide health and fitness services (Anytime Fitness, Weight Watchers International). There were also a few venture capital-backed app families, including the Noom app family, the Azumio app family, and Headspace, each of which had acquired several million dollars in venture capital.

We identified several commercial entities with financial relations to multiple app families. These were largely venture capital firms or major corporations: Kleiner Perkins Caufield & Byers (relations to 4 apps), Felicis Ventures, Founders Fund, Oprah Winfrey, Aetna, Rock Health, Qualcomm Ventures, Google Inc, Khosla Ventures, and Sequoia Capital (relations to 3 apps each).

Commercial “partnerships.” Fifty-three app families (24%) reported at least 1 commercial “partnership” in their store descriptions or on linked Web sites. Of these, app families had an average of 3.07 commercial partnerships (SD = 3.61). Although seldom explicitly defined, partnerships appeared to promote the app or related products and services. For example, the linked Web site from CalorieKing’s store description listed “partners” including Aetna (a health insurance corporation), Anytime Health (a fitness franchise), and Roche, Sanofi-Aventis, and Johnson & Johnson (pharmaceutical companies). The Web site stated, “We partner when we believe the combination of efforts will place better long-term weight management products and services within reach of more people than would be possible otherwise.” In some cases, “partners” represented corporate clients. In others, partners were corporate sponsors who paid for health content. For example, Pregnancy Tracker’s linked Web site, WhatToExpect.com, posted: “WhatToExpect.com” regularly seeks sponsorships from relevant organizations and manufacturers dedicated to providing

pregnancy, parenting, and preconception information. In some cases, sponsors provide funding for the creation of What to Expect content without having any influence over it.”

Advisor Network

Fewer than one third of app families (68 of 222; 31%) attributed content to authors or advisors (Figure C, available as a supplement to the online version of this article at <http://www.ajph.org>). Only 3 app families had an advisor in common, whereas the majority were surrounded by their own distinct group of experts. Alternative health, lay experts, or other nonscientific experts such as chefs, professional athletes, or celebrity trainers were the sole source of named expertise for nearly half of the app families that attributed content to an advisor (33 of 68; 49%). Only 19 app families (19 of 68; 28%) drew expertise exclusively from named individuals with scientific or clinical credentials. However, a similar number (16 of 68; 24%) engaged named authors or advisors who represented both scientific and nonscientific perspectives. For nonscientific advisors, app-related content frequently linked back to a personal brand (e.g., training studio or cookbook). For scientific advisors, many had affiliations with research universities but also with for-profit entities such as fertility clinics, consulting practices, or monetized blogs. Eleven individuals with scientific or clinical credentials also occupied a financial role such as developer, founder, or investor, including individuals such as Mehmet Oz and Deepak Chopra.

Another 23% of app families (51 of 222) mentioned a content source in their store description or on their linked Web site, but there was no evidence of actual collaboration. We characterized these mentions as a form of “name-dropping,” or reference without proper citation at best. For example, Azumio, the makers of Argus, advertised that “Azumio works closely with researchers, clinicians, and professors from top universities including Stanford and UCSF,” but these individuals were not named.

DISCUSSION

Prominent health and fitness apps in the US, Canadian, and Australian markets are

largely North America-based private companies with a variety of financial stakeholders, and are focused on fitness and activity tracking. Despite sampling only a fraction of the mobile health market, we found that a number of these sampled apps are tied to the same companies through financial relations.

About one fourth of the developers in our sample were individuals and the majority of apps remained peripheral to the financial network, suggesting a more distributed market. However, the connected core was characterized by larger corporate entities, including technology, fashion, and pharmaceutical companies and venture capital firms. This reflects recent analysis suggesting that the app market may be concentrating among a few, established companies and that the stereotypical garage-based startup may no longer reflect mobile health.² A small number of corporations currently account for the majority of revenue and downloads generated by health apps: only 2% of health app developers account for more than 1 million downloads or generate more than US\$5 million a year.²

Public health approaches focused on corporate influences on health are thus applicable to mobile health.^{10,15} Freudenberg has called on public health to more closely examine the operations, strengths, and vulnerabilities of the “corporate consumption complex,” which he argues is the most powerful influence on population health.¹⁰ This complex is a network of organizations that support the dominance of corporations, which exist to maximize profits.¹⁰ In the context of the technology industry, as our analysis shows, health apps exist in a network of venture capitalists, commercial partners, scientists and clinicians, and celebrities, with major corporations at the center. Missing from this analysis are the digital advertisers, data brokers, industry associations, lawyers, lobbyists, and regulators.

In fact, the bulk of the mobile health “ecosystem” remains hidden from public view, making it difficult to scrutinize the potential for commercial bias and the consequences for app content, targeted marketing, or consumer privacy. Furthermore, a minority of app families (28%) attributed content to an author or adviser, further reducing transparency and preventing

accountability for content or conflicts of interest.

To date, public health professionals have largely focused on app content, criticizing the lack of evidence-based content or theoretically based approaches.^{3,4,26,27} Thus, researchers have framed partnerships with app developers as the means to address the safety and quality of health apps^{4,27,28} and have taken for granted that scientific or clinical authorship is a marker of app quality.⁹ Our findings suggest that scientific advisors may hold multiple roles in relation to the app, and may frequently have other commercial interests (e.g., for-profit fertility clinics, meditation centers, skin care products). One well-documented corporate tactic is the use and distortion of scientific research to promote products and minimize harms.¹⁵ Our findings show that developers are also using clinicians, scientists, and research organizations to increase their credibility; although this is sometimes only name-dropping, it can provide mixed signals to consumers attempting to identify safe and quality apps. This analysis confirms a gap, noted by other studies, between the scientific and commercial faces of mobile health,²⁹ suggesting the need for greater involvement of public health professionals in app development, but also transparency and independence in providing expert evaluation. Disclosure of researchers’ and practitioners’ financial ties, regardless of the industry, should be routine, and research into conflicts of interest and resulting biases in the context of mobile health is required.

Public Health Implications

The focus of public health professionals on app content limits their input to a highly narrow scope within health app development and fails to account for the population health effects of the commercial practices underpinning health apps. One of the most problematic aspects of the corporate consumption complex is the promotion of hyperconsumption.¹⁰ Even free apps exist in a highly commercialized space in which consumers must buy a smartphone and a data plan and use a credit card to access an app store.¹⁸ Our findings suggest that health apps are frequently monetized and link to the promotion of products and services through networks of financial relations. This supports

the critique that mobile health may reinforce health inequalities by focusing on the “White, worried, and well” who are ideal marketing targets, but not necessarily the ones who could most benefit.³⁰ Public health needs to challenge the commercialization of health that renders health more individualized and draws attention away from the social determinants of health.¹³

The public health implications of health apps may extend well beyond use of the app itself. Corporate tactics such as tax avoidance, public relations, and lobbying have the power to reshape policies that directly affect population health.¹⁵ For example, e-mails between regulators at the Food and Drug Administration and executives at Apple, released through a Freedom of Information Act request, document regular meetings about the regulation of software as a medical device and reveal that Apple repeatedly requested that its involvement not be disclosed.³¹ Thus, Apple, a central entity in our network analysis, may be in a position to influence regulatory developments in ways not necessarily consistent with public health goals.

Health and fitness apps have the potential to widely disseminate health information and to promote health behaviors. However, attention to the commercial entities that control the content and data generated through mobile health apps may provide insights into other powerful influences on public health.^{19,32} Future research could seek to understand the relationship between various revenue models, data-sharing policies, or types of companies and the effectiveness of an app in terms of health behaviors or outcomes.¹¹

Limitations

The market for mobile health apps rapidly changes—our analysis is based on a cross-sectional sample of a small sample of 297 top-ranked health and fitness apps available in November 2015, with data collected up to April 2016. It is likely that the apps available and their financial relationships have changed. Although the US market is the largest for health apps, this sample represents only a portion of the global health app market and, notably, only English-language apps.

Most health app developers have only recently entered the market,² and many are private companies or individuals about which

there is little publicly available information. We could not verify the accuracy of promotional materials or investment data. This analysis likely underestimates the extent of financial ties and highlights the challenge of studying commercial interests where information is largely not publicly reported.

Our classification of advisors as scientific or nonscientific was based on experts' qualifications as reported in app promotional materials; we did not verify their accuracy, and some credentials may have been missed. As this analysis shows, this dichotomous classification fails to capture the influences on an individual holding multiple positions (e.g., advisor, developer, investor) or those with diverse training. It also suggests that the presence of advisors with scientific or clinical credentials should not be used as a proxy for app quality, as it fails to account for conflicts of interest and cannot guarantee that advice is evidence based.

Conclusions

Although mobile health and fitness apps have the potential to benefit public health and provide innovative solutions for tailored health promotion, their development and dissemination are commercialized. The involvement of public health professionals in the mobile health app market should be guided by critical perspectives that identify and evaluate the effects of commercial influences on the health of app users. As this market is largely unregulated, there are few mechanisms to ensure that commercial interests align with public health goals. **AJPH**

CONTRIBUTORS

Q. Grundy conceptualized the study, supervised and participated in data collection and analysis, wrote the first draft of the article, and revised subsequent drafts. F. Held performed the network analyses, created the figures, and critically revised the article. L. Bero conceptualized the study, supervised all stages of the research, and critically revised the article.

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HUMAN PARTICIPANT PROTECTION

Because this research did not involve human participants, protocol approval was not required.

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